

FULL-SCALE SYSTEM IMPACT ANALYSIS

Digital Document Storage Project

(NASA-CR-189793) FULL-SCALE SYSTEM IMPACT
ANALYSIS: DIGITAL DOCUMENT STORAGE PROJECT
Final Report (NASA Scientific and Technical
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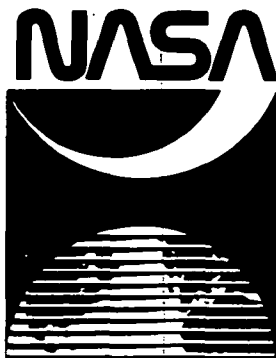
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STI PROGRAM
SCIENTIFIC &
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Scientific and Technical Information Facility

FULL-SCALE SYSTEM IMPACT ANALYSIS

Digital Document Storage Project

FINAL

SUMMARY: The DDS Full-Scale System can provide cost-effective electronic document storage, retrieval, hard-copy reproduction, and remote access for users of NASA Technical Reports. The desired functionality of the DDS system is highly dependant on the assumed requirements for remote access used in this Impact Analysis.

It is highly recommended that NASA proceed with a *phased, communications requirements analysis* to ensure that adequate communications service can be supplied at a reasonable cost in order to validate recent working assumptions upon which the success of the DDS Full-Scale System is dependent.

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MANAGEMENT SUMMARY

This Impact Analysis report presents the results of an analysis conducted at the NASA Scientific and Technical Information (STI) Facility during the first quarter of Federal Fiscal Year 1990. RMS Associates, the management contractor for the STI Facility, prepared this Impact Analysis report in response to NASA Headquarters Technical Directive (TD) 88-061 issued under contract NASW-4070. This TD has been the primary vehicle for directing the Digital Document Storage (DDS) project at the STI Facility. The report was prepared consistent with the Revised Work Plan provided by STI Facility staff in response to TD 88-061. The Level of Effort (LOE) resources that were applied to this Impact Analysis were authorized through NASA Task Assignment (TA) 90-31.

Using assumed requirements for remote access, this analysis concludes that desired functionality for the proposed DDS Full-Scale System can be achieved. The most critical element, however, in the system's ability to deliver electronic document images to remote sites will be long-distance communications service. The communications service currently used to support remote access to STI Facility information systems must be augmented in order to support the intermittent transmission of large digital document image files.

It has been assumed that NASA's Program Support Communications Network (PSCN) can and will be able to supply sufficient communications service to support adequate response at DDS remote retrieval workstations. This Impact Analysis concludes with a strong recommendation for a phased, communications requirements analysis in order to ensure that this critical element is adequately addressed.

1-INTRODUCTION AND OVERVIEW

NASA currently is examining the desirability of using digital imaging technology to facilitate operations and enhance services at its Scientific and Technical Information (STI) Facility located at Linthicum Heights, Maryland. As part of that effort, RMS Associates, NASA's STI Facility management contractor, completed the Digital Document Storage (DDS) project's Digital Imaging Technology Assessment report and presented it to NASA in August of 1989. The Digital Imaging Technology Assessment report contains a proposal for a three-stage DDS project implementation: the Prototype, Pilot Production, and Full-Scale Systems.

The DDS staff has recommended that the DDS Prototype System be acquired and implemented at the STI Facility to facilitate further investigation of the technology and to develop specific requirements for the Pilot Production System. NASA Headquarters Code NTT required STI Facility staff to produce three documents. The first, an acquisition plan for the DDS Prototype System, is being reviewed by NASA Headquarters staff. The second, the Cost/Benefit Analysis report, evaluated the relative merits of three alternatives for providing on-demand remote access from NASA Code NTT to a postulated Pilot Production System at the STI Facility. The report in which this Cost/Benefit Analysis is presented is currently under review at NASA Headquarters. This report, the Impact Analysis, is the third document requested by NASA. It contains an analysis of the impacts of the potential Full-Scale System in terms of equipment, personnel, and services.

The scope of the Impact Analysis and the description of the proposed Full-Scale System are explained in section 2-*BACKGROUND*. In section 3-*APPROACH*, assumptions and constraints that form the basis for the analysis in subsequent sections are presented as well as the analysis methodology. The current service level and projected DDS service levels are described in section 4-*DOCUMENT SERVICE ANALYSIS*. In section 5-*REMOTE COMMUNICATIONS ANALYSIS*, the document service model is characterized by the impact to electronic delivery methods from the STI Facility to 16 remote sites. Specific impacts to operational components, both existing and proposed for future implementation, are described in detail in section 6-*FULL-SCALE SYSTEM IMPACTS*. Costs for the additional elements of the Full-Scale System beyond the Pilot Production System costs are provided in section 7-*COST SUMMARY*. Sections 8-*ANALYSIS OF FINDINGS* and 9-*RECOMMENDATIONS* contain the findings and recommendations regarding the implementation of the proposed DDS Full-Scale System.

The results of this Impact Analysis suggest the feasibility of proceeding with the DDS Full-Scale System. The DDS system has significant short- and long-term advantages, including both tangible and intangible improvements to service and the establishment of a sound technological foundation for the future. Evaluation of system functionality and potential impacts, by way of a thorough prototyping activity as suggested in the DDS Acquisition Plan, is essential. After an adequate amount of experience and evaluation of this prototype, major

assumptions that underlie the DDS Pilot Production and Full-Scale Systems can be tested and refined. Such testing and refinements can reduce the level of implementation risk and maximize the benefits to be derived by implementing DDS through the Full-Scale System.

2-BACKGROUND

Having discussed the Impact Analysis and DDS project in general terms in the introduction, this section provides important background information upon which the Impact Analysis has been developed. The scope of this Impact Analysis is presented with an emphasis on anticipated improved service as a result of the DDS Full-Scale System. Corresponding functional characteristics that recently have been assumed are described in a general fashion and then in greater detail.

2.1 Scope of Analysis

This Impact Analysis has been developed according to the guidelines as set forth in the NASA Automated Information Management (AIM) Project Feasibility Study and the DDS Revised Work Plan, dated October 11, 1989. The STI Facility staff estimates that the remote-access delivery method is the most sensitive cost element for Full-Scale System implementation at the estimated 16 NASA Centers that would be involved as DDS remote sites. The purpose of this study is to explore various impacts for delivering a remote access capability to all 16 NASA Centers in terms of equipment, personnel, and services.

NASA Headquarters staff has directed the DDS staff to make broad assumptions concerning system requirements, document characteristics, remote user profiles, and system configuration for the Full-Scale System, in order to develop a reasonable scenario from which to assess potential impacts. Therefore, this Impact Analysis is not based upon detailed requirements analysis and workload characteristics.

Accordingly, the DDS staff has developed and documented an assumed system configuration for the Full-Scale System upon which all subsequent analysis will be based. A functional description of the characteristics of the proposed system and each of the major subsystems that comprise the Full-Scale System are presented in section 2.2 of the Cost/Benefit Analysis report, dated December 30, 1989. This functional description is an extension of the general functionality presented in section 2.4 of the DDS Digital Imaging Technology Assessment, dated August 7, 1989; the DDS Revised Work Plan; and the Cost/Benefit Analysis report.

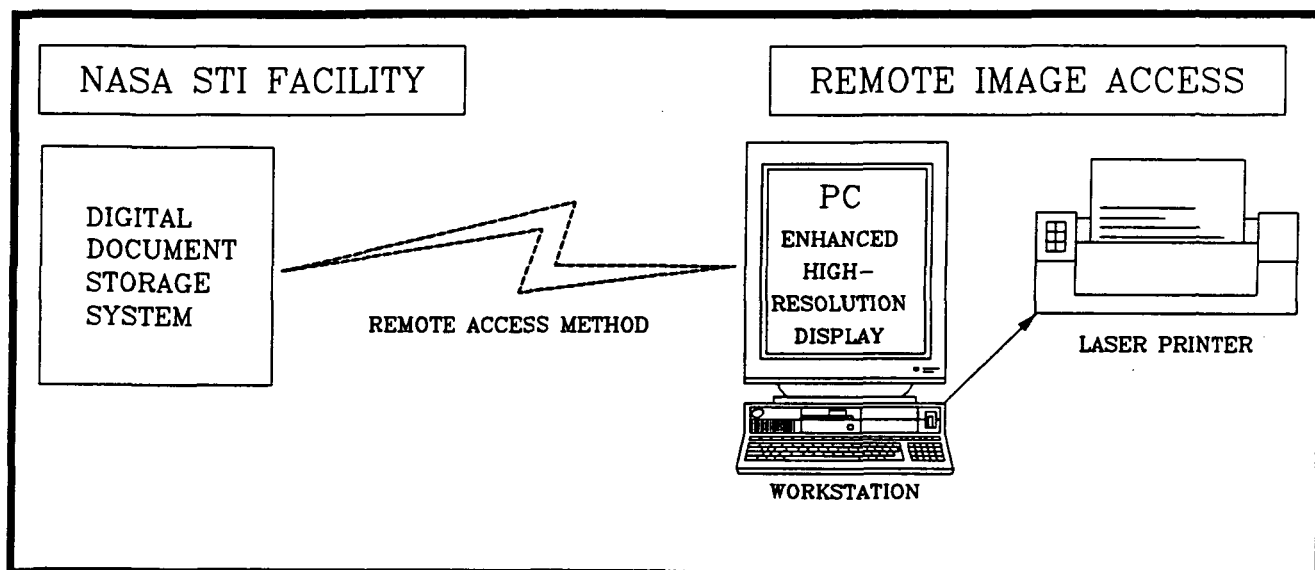
This Impact Analysis was performed, based upon efforts by STI Facility staff, to prepare a high-level generic DDS system design. These efforts did not consist of a systematic definition of requirements based upon analysis and detailed design activities—these necessary steps are assumed to precede the actual development of the DDS Full-Scale System.

2.2 Summary of Remote Access Retrieval Capability

The remote user at NASA Headquarters or a selected NASA Center will be able to request either an entire document by accession number or its subparts by a Table of Contents lookup. Once these images are received, they can be either viewed on the remote workstation monitor

or directed to be printed locally. This will be an automated process requiring no previous training to operate the subsystem or special skills to navigate for access. NASA Technical Reports with limited document distribution attributes (that is, LSTAR 1X series reports) will not be electronically transmitted to remote sites as a precaution against unauthorized access or viewing. Figure 2-1, the DDS remote workstation, shows the components necessary for remote-access retrieval of digitally stored document images.

Figure 2-1. *Proposed DDS remote workstation configuration.*



The remote workstation provides the user with electronic images of NASA Technical Reports for display, manipulation, storage and printing. There are two postulated modes of operation at the remote workstation: batch/deferred or interactive processing. In batch/deferred mode, documents are transferred, at a specified time, from the document archive to the local storage medium (hard disk, rewritable disk, or tape drive) for later processing. In interactive mode, the remote user will request a specific document by accession number and resolution level (low for display only and high for printing letter-quality pages).

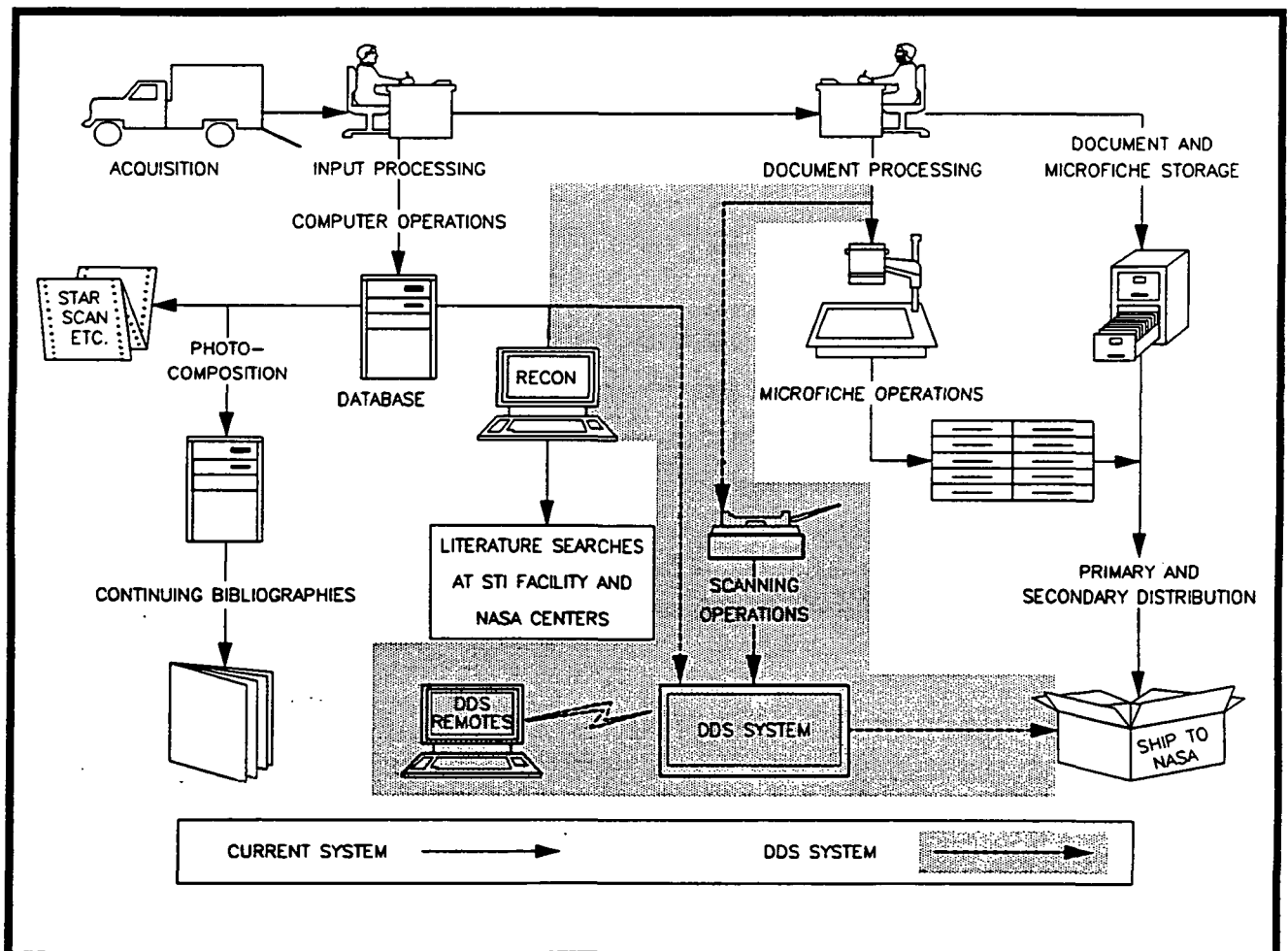
If the desired document is available within the DDS document archive, then the first page image will be displayed on the remote workstation screen. If the requested accession number is not available within DDS, then an appropriate warning message will be displayed on the remote user's screen. The simplest form of interactive viewing is the sequential browsing of images in page sequence using the cursor keys or the page up or page down keys. Context sensitive help is available at any point in the remote retrieval session by selecting the F1 function key. See appendix C of the Cost/Benefit Analysis report, for a more detailed description of a remote-access workstation session.

NASA's objective of nonsequential retrieval of document subparts will be met when Tables of Contents are available within reports. This feature will be preserved with document analytics to retain conformity with current NASA/RECON database structures.

2.3 Environment

The proposed DDS Full-Scale implementation is, with few exceptions, designed to operate as a totally independent automated system with no interfaces to existing application systems or document processing work flows. Figure 2-2, the STI Facility and DDS system interface, shows the interface of the DDS system to the existing NASA/RECON STI Facility operations. Because the DDS platform will use stand-alone, special-purpose, PC-based workstations to be procured specifically for that purpose, hardware and operating system compatibilities with other, existing systems are not considered.

Figure 2-2. STI Facility and proposed DDS system interface.



Another issue is the need to coordinate centralized DDS document request processing with the existing STI Facility document request work flow. A detailed process definition effort is planned at the beginning of the Pilot Production System to establish the best method for interrupting the current work flow to divert appropriate FF492 requests to the DDS system for processing. A high-level analysis was conducted to assess major impacts, which are presented in section 6.2, *Personnel*, but does not represent a detailed systems analysis effort resulting in a thorough process description.

3-APPROACH

The previous section dealt with background information such as the scope of this Impact Analysis and a description of the DDS Full-Scale System from a functional viewpoint. This next section identifies a number of critical assumptions upon which this Impact Analysis is based. Also, assumptions and constraints pertaining to this analysis effort are provided. These assumptions and constraints pertain to:

- * DDS Full-Scale System configuration
- * Document characteristics and capture volumes
- * Electronic reproduction volume
- * Remote-access characteristics
- * Local communications traffic
- * Access control

The methodology for performing this Impact Analysis is discussed at the end of this section.

3.1 Assumptions and Constraints

A number of assumptions about communications requirements and system design of the DDS functionality at the STI Facility and remote sites were made in order to analyze the impacts of the Full-Scale System implementation. Additionally, until the DDS Prototype and Pilot Production Systems are acquired and evaluated, critical system characteristics will be unavailable. The following narrative highlights critical aspects underlying this Impact Analysis that were based upon minimal information and data sources. Any change in the following assumptions could affect the results of this Impact Analysis, and would require additional analysis.

3.1.1 System Constraints

The life cycle for the Pilot Production System is five years, followed by a five-year life cycle for the Full-Scale System. Although it is highly unlikely that this amount of time would be required to fulfill the Full-Scale System objectives as stated in section 1 of the Cost/Benefit Analysis report, this Impact Analysis was developed under the premise of a Full-Scale System five-year life cycle.

DDS is designed to provide centralized electronic capture and storage of a maximum of 5,000 NASA Technical Reports yearly, and approximates 90 percent of the NASA Technical Reports acquired at the STI Facility annually. All document capture is based on availability of original hard-copy reports from a day-forward viewpoint; neither back-file conversion nor microform scanning has been assumed in the Full-Scale System.

3.1.2 System Configuration

The proposed DDS Full-Scale System configuration is comprised of the existing Pilot Production System equipment at the central processing site (located at the STI Facility), communications equipment, and 16 remote workstation with accessories. For ease of discussion, table 3-1, the NASA Centers proposed as DDS remote sites, identifies each site by its standard abbreviation.

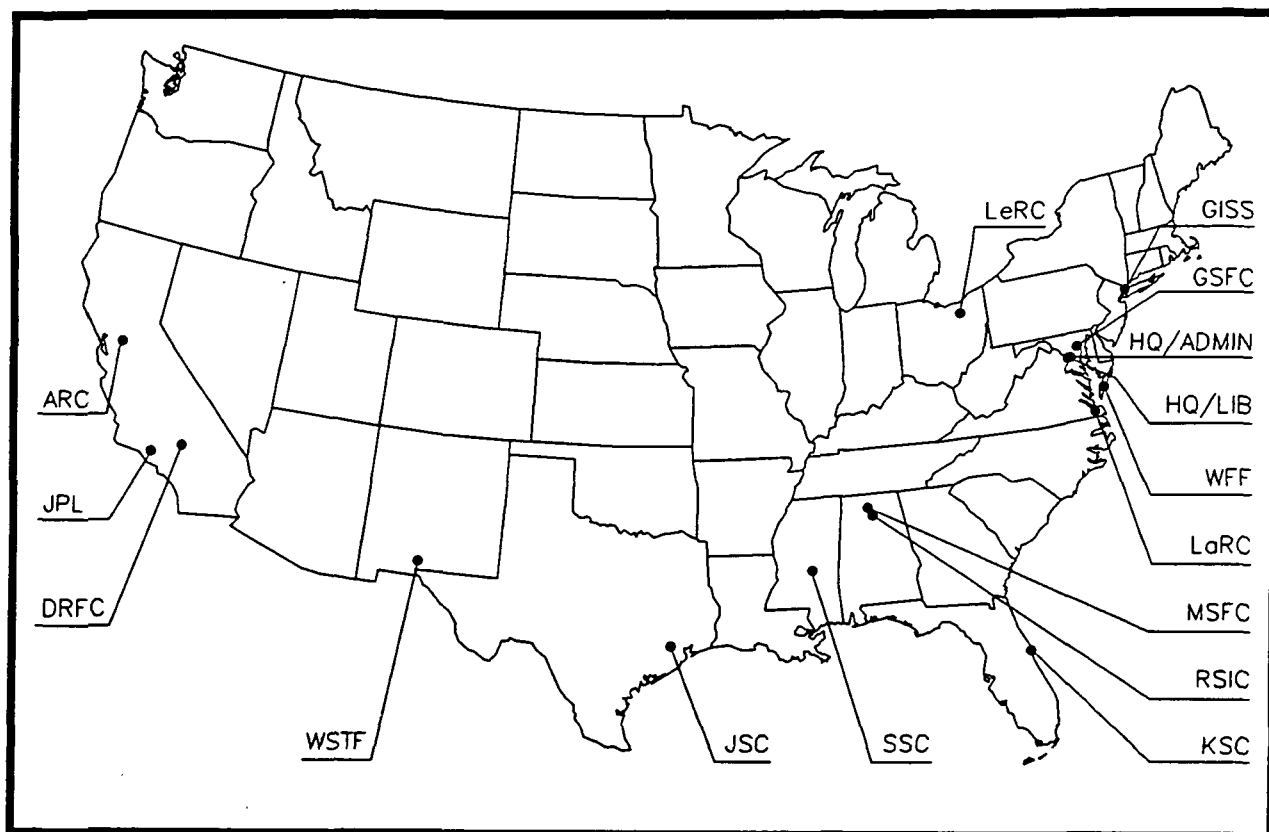
TABLE 3-1. NASA Centers proposed as DDS remote sites.

ABBREVIATION	NASA CENTER (DDS REMOTE SITE)	LOCATION
1. ARC	Ames Research Center	Moffett Field, CA
2. DFRC	Hughes L. Dryden Flight Research Center	Edwards AFB, CA
3. GISS	Goddard Institute for Space Studies	New York, NY
4. GSFC	Goddard Space Flight Center	Greenbelt, MD
5. HQ/ADMIN	NASA Administrative Headquarters Code NTT	Washington, DC
6. HQ/LIB	NASA Headquarters Library	Washington, DC
7. JPL	Jet Propulsion Laboratory	Pasadena, CA
8. JSC	Lyndon B. Johnson Space Center	Houston, TX
9. KSC	Kennedy Space Center	Titusville, FL
10. LaRC	Langley Research Center	Hampton, VA
11. LeRC	Lewis Research Center	Cleveland, OH
12. MSFC	Marshall Space Flight Center	Huntsville, AL
13. RSIC	Redstone Scientific Information Center	Huntsville, AL
14. SCC	John C. Stennis Space Center	Bay St. Louis, MS
15. WFF	Wallops Flight Facility	Wallops Island, VA
16. WSTF	White Sands Missile Test Facility	Las Cruces, NM

Figure 3-1, the locations of the proposed DDS remote sites, shows the selected NASA Centers.

A graphic representation of the Full-Scale System is provided in Figure 3-2, the Full-Scale System configuration. The major hardware and software components required at all 16 locations are listed in appendix *A-Assumed Full-Scale System Configuration*. The guidelines for the Pilot Production and Full-Scale Systems configurations and system acquisition strat-

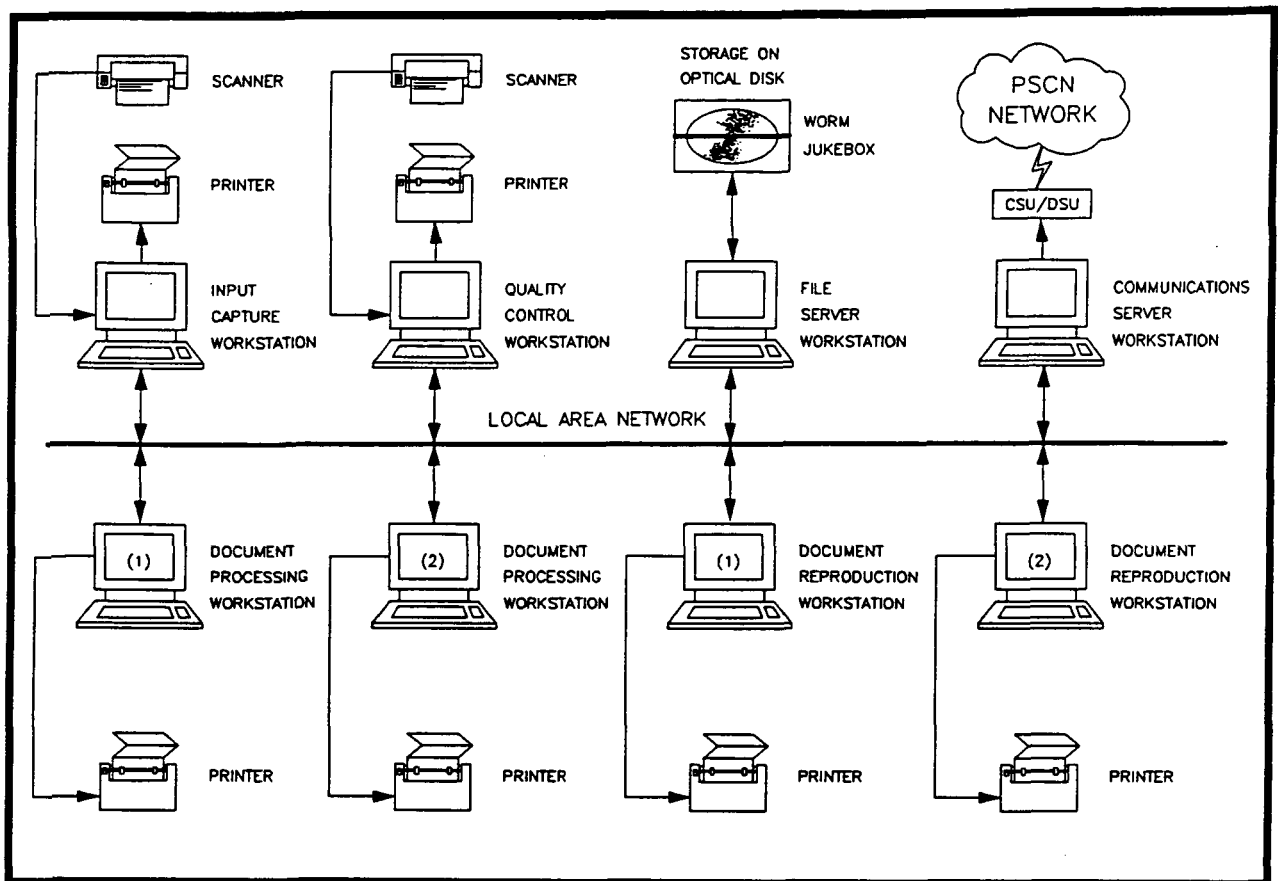
Figure 3-1. Locations of the proposed DDS remote sites.



egies are as outlined in the Digital Imaging Technology Assessment report. Additionally, it was assumed that the implementation strategy will be an unbundled, component-level procurement with system integration performed at the STI Facility and customized for the NASA STI Facility environment. The open architecture design for the Full-Scale System will enable the insertion of new technology in the future that could facilitate the incremental and modular incorporation of new products, referred to as technology insertion.

Differences between functionality described in the Digital Imaging Technology Assessment report and later NASA Headquarters Code NTT guidance involve a scaling down of mainframe-level integration with NASA/RECON and the elimination of full-text capture, search, and retrieval at this time. Remote workstation functionality details are based on materials presented at the *May 1989 NASA STI Conference* and the assumed functional capabilities discussed in section 2.2.1 of the Cost/Benefit Analysis report.

Figure 3-2. Proposed DDS Full-Scale System configuration.



3.1.3 Document Characteristics

Specifics of the types of documents to be captured and stored in the proposed system can greatly affect the scanning, quality control, image enhancement, and transmission in digital, bitmapped format of raster-image document pages, in addition to the skill level required to accomplish those tasks. Volume projections for the entire Full-Scale System life cycle have their basis in assumptions about the average page size per acquisitioned document. Also, other system design considerations (such as access limitation) are impacted by document characteristics.

The assumed document characteristics are the following:

- Page specifications for document scanning are:
 - must be 8.5-by-11-inch size paper
 - conforms to scanner's operational thresholds (range of paper thickness/texture)
- Scanned pages will be stored as bilevel (black-and-white)
- The average number of pages per document accession is 50
- No classified or limited distribution documents will be transmitted to remote sites

- Estimated percentage of graphics, line art, and halftone images in an average document is 30 percent
- A document is defined as a Scientific and Technical Information Modular System (STIMS) database accession and is equated with a database surrogate record. Due to the procedure for creating database accessions/records, a single printed NASA Technical Report could result in the creation of multiple database accessions/records. In all instances in this report where the term "document" is used, it is used to refer to a STIMS database accession/record.

3.1.4 Document Acquisition

Document acquisition for the DDS Full-Scale System is envisioned to occur after the current microfiche capture procedures are completed, just as in the Pilot Production System. This will minimize the operational impact on existing document accessioning efforts. Table 3-2, the document acquisition volume, gives the cumulative number of documents and pages that is expected to be archived during each of the five years of the Full-Scale System.

TABLE 3-2. *Document acquisition volume.*

OPERATIONAL YEAR	ANNUAL VOLUME (DOC.)	AVG. DAILY VOLUME (PAGES)	ARCHIVE SIZE (DOC.)	ARCHIVE SIZE (PAGES)
One	5,000	1,000	30,000	1,500,000
Two	5,000	1,000	35,000	1,750,000
Three	5,000	1,000	40,000	2,000,000
Four	5,000	1,000	45,000	2,250,000
Five	5,000	1,000	50,000	2,500,000

3.1.5 Reproduction Workload at the NASA STI Facility

The Full-Scale System is envisioned as the culmination of a number of planning, analysis, design, development, testing, and acceptance activities for the three system stages discussed in section 3.1, *Assumptions and Constraints*. In table 3-3, the assumed DDS project plan, a tentative schedule of these events is provided for the basis of other assumptions throughout this Impact Analysis.

Assuming that the DDS Prototype System is procured and adequate staffing is provided, the Prototype System is assumed to be in operation for one year until the middle of 1991.

TABLE 3-3. *Assumed DDS project plan.*

START DATE	END DATE	ACTIVITY
1/90	6/90	Prototype procurement
7/90	6/91	Prototype operation and evaluation
1/91	12/91	Pilot Production System procurement
1/92	12/96	Pilot Production System operation and evaluation
1/96	12/96	Full-Scale System procurement
1/97	12/01	Full-Scale System operation and evaluation

The Pilot Production System is assumed to be operational from 1992 until the end of 1996. The Full-Scale system should be operational from the beginning of 1997 until the end of 2001.

The projected volume of reproduced pages at the STI Facility by operational year is presented in table 3-4, the estimated reproduction workload at the STI Facility in thousands of pages. The DDS archive percentage (ARC%) was derived from figure 3, number of pages printed for 1988 document requests by accession year, from the Reproduction Volume (Blowback) Report. As depicted in the second table in this section, the DDS archive percentage is assumed to increase with each year of document capture in proportion to the document requests per accession year, based on 1988 document requests.

The number of pages of NASA Technical Reports reproduced in 1989 was approximately 732,000, as calculated from table 16 in the monthly Report on Facility Operations from 1989. It is assumed that each year would result in a 3-percent compounded growth in number of reproduced pages. This growth factor produces an estimated annual reproduction volume of 800,000 by the end of 1992, the first operation year of the Pilot System. By the end of 2001, the reproduction volume is projected to be 1,044,000 pages per year. It is also assumed that a percentage of pages will be reproduced by DDS in replacement of stock copies since the DDS reproduction should be of high quality and minimal cost. The total number of stock copy pages, with the 3-percent growth factor included, is provided in the column labeled STOCK W/O DDS. The initial value of 675,000 for 1989 was derived from table 12 of the monthly Report on Facility Operations for 1989. The projected number of pages that theoretically could be replaced is shown in the column labeled STOCK WITH DDS. The total number of reproduced pages by DDS at the maximum per year is shown as the sum of REPRO WITH DDS and STOCK WITH DDS.

TABLE 3-4. *Estimated reproduction volume at the STI Facility, in thousands of pages.*

END CAL. YEAR	PILOT PROD. YEAR	FULL- SCALE YEAR	DDS ARC. (%)	REPRO. W/O DDS	REPRO. WITH DDS	STOCK W/O DDS	STOCK WITH DDS	DDS TOTAL PAGES
1989				732		675		
1990				754		695		
1991				777		716		
1992	One		11%	800	88	738	81	169
1993	Two		22%	824	181	760	167	348
1994	Three		28%	849	238	783	219	457
1995	Four		35%	874	306	806	282	588
1996	Five		39%	900	351	830	324	675
1997		One	58%	927	538	855	496	1,034
1998		Two	61%	955	583	881	537	1,120
1999		Three	65%	984	639	907	590	1,229
2000		Four	69%	1,013	699	934	645	1,344
2001		Five	74%	1,044	772	962	712	1,484

3.1.6 Remote Access

The remote-access delivery volume has the following three components as will be discussed in section 4.2.1, *DDS Traffic Volume*.

- Diverted pages from central reproduction
- Diverted pages from stock copy distribution
- Supplemental volume due to latent access demand, growth factors, local blowback replacement, and unknown factors.

The following assumptions are relevant to the remote access traffic projections presented in section 4.2.1:

1. Hours of operation: 8:00 a.m.—8:00 p.m. EDT (Same as NASA/RECON)
2. Nationwide access
3. Deferred requests will be serviced between 5:00–8:00 p.m.
4. Equal access and priority will be provided to each remote site

5. No chargeback for using DDS remote access
6. Remote workstation functionality (batch or deferred transmission)
 - a. If a LAN-server conflict or communications-server traffic impact arises, will implement a sub-LAN as an upgrade
 - b. Program Support Communications Network (PSCN) solution—NASA Libraries will install tail 56 Kbps communications lines using PSCN (cost not quantified) and DDS-authorized workstation configurations
 - c. Text transaction traffic will be minimal
7. All local equipment at remote site is dedicated for and supplied (approved) by DDS—no existing equipment will be used.
8. PSCN will provide 56 Kbps service continuously across all communications lines, point-to-point. Each NASA Center will provide its own workstation.
9. Interactively transmit only one page at a time. Document file and multipage transfers will be deferred and processed at the most convenient time for the user and the DDS system (depending on workload).

An important objective is to minimize the cost involved in delivering the document images to the remote site to encourage the use of this new service. Primary benefits to processing and maintaining a digitized document database centrally are the consolidated services, access capability, minimizing of media handling, and coordination with NASA/RECON.

3.1.7 Local Communications Traffic

No local area communications bottleneck is expected within the STI Facility DDS Full-Scale System due to image-capture traffic and retrieval requests because of the temporary image-buffering design using a magneto-optical (M-O) drive at the quality control workstation. This buffering minimizes image traffic in all cases, which should reduce the chance of collision on the LAN. Also, the remote-access retrieval traffic is expected to be infrequent, intense, and of limited duration (less than one hour). Coordination of local and remote traffic will be accomplished by way of file management access priorities. The use of a sub-LAN or LAN upgrade in terms of capacity and bandwidth is planned for the Full-Scale System.

3.1.8 Access Control

The only planned access to DDS images is by entering a valid STIMS database accession number. Since classified documents will not be stored in the Full-Scale System, no additional security is required. Although stored in DDS, limited distribution documents (that is, the LSTAR 1X series reports) will not be available remotely through DDS.

3.2 Methodology

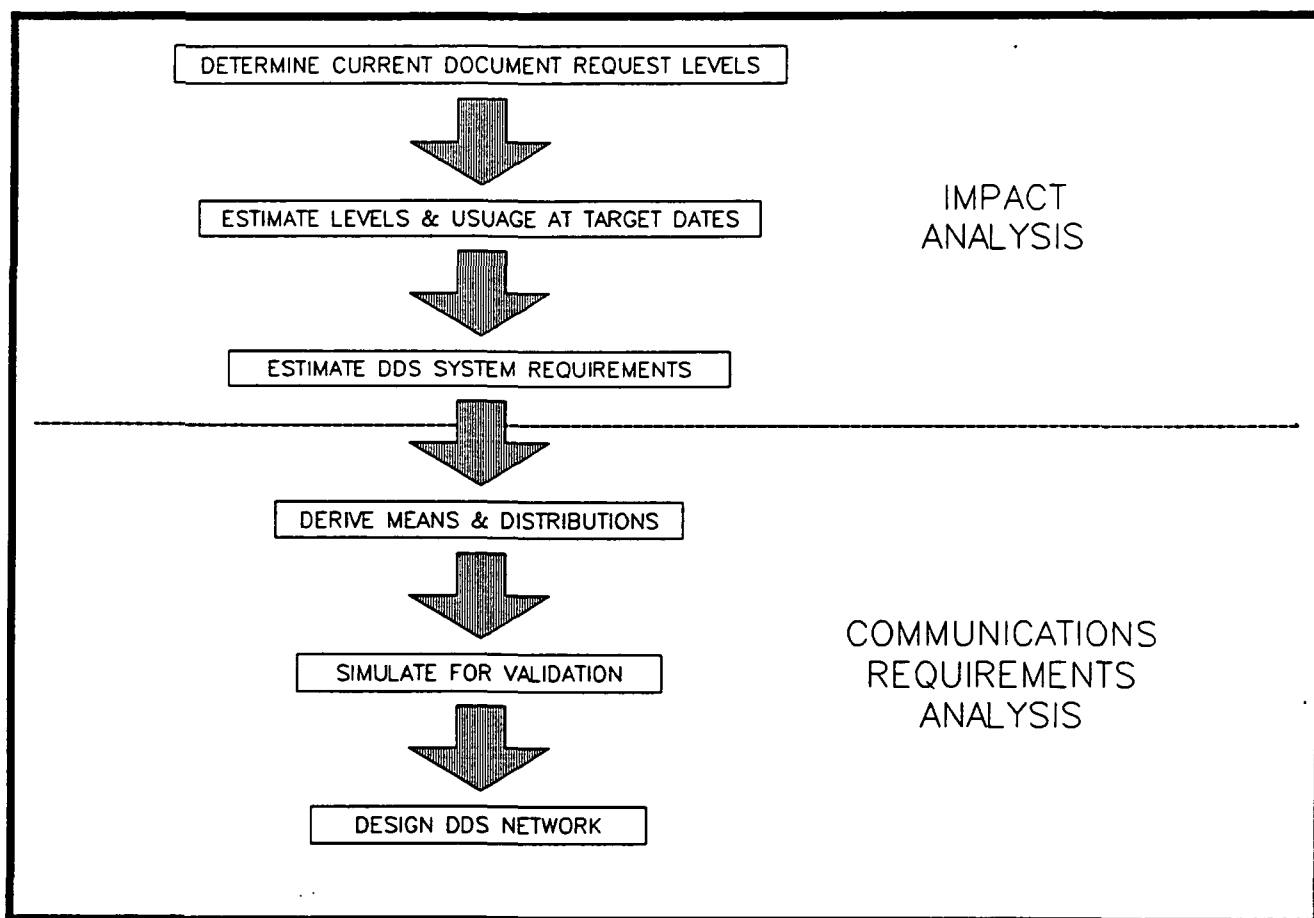
This Impact Analysis was conducted using projections based upon limited historical data, STI Facility experience, and quantitative assumptions. Despite the best analytical efforts on the part of the DDS staff, this Impact Analysis does not constitute a system design specification or logical equivalent. A high-level, conceptual system design has been assumed, based on the assumed functional requirements that were stated in section 2 of the Cost/Benefit Analysis report. The DDS staff continued with these assumptions during the preparation of this Impact Analysis. One NASA Center, namely LeRC, offered information regarding estimated monthly volume in pages from local library microfiche blowback for a single month. Most other figures were extracted from STI Facility reports and computer statistics.

The development of the document service model, described in sections 4-*DOCUMENT SERVICE ANALYSIS* and 5-*REMOTE COMMUNICATIONS ANALYSIS*, began with the establishment of baseline document request volumes for current request servicing activities. Then the page volumes were extrapolated into the future to arrive at realistic numbers for Pilot Production and Full-Scale Systems. Finally, a reasonable remote access scenario was developed to include page volumes for diverted documents from central reproduction and stock copy requests. In addition, supplemental electronic document transmissions as a result of nonsequential access—a completely new functional capability unavailable prior to the implementation of DDS—was included in this scenario.

4-DOCUMENT SERVICE ANALYSIS

This section describes in detail the analysis path from the existing NASA Technical Report production workload to arrive at analytically formulated results to project the estimated needs for DDS Full-Scale System remote communications. Specific assumptions and constraints pertaining to this analysis will be provided in each section, where appropriate. A level of required communications service will be derived for planning and performance/price comparison purposes. Figure 4-1, the DDS remote communications analysis methodology, shows the steps to take in the Impact Analysis and the recommended communications requirements analysis.

Figure 4-1. *DDS remote communications analysis methodology.*



A document service model was developed as the first step in the communications requirements analysis. The results of manipulating this business model provide sufficiently accurate, but approximated, parameters to indicate the appropriate paths for future analysis. Although this business model provides approximate parameters, it should not be interpreted to provide the detailed analytical results typically obtained from refined scientific and engineering models. It is assumed that the Full-Scale System will start after a Pilot Production System of five years, during which some 25,000 NASA Technical Reports will have been digitized and stored on

optical disk at the STI Facility. It is this population that the DDS system will make remotely available as an on-demand resource for viewing and printing. This represents approximately 1,250,000 pages in the DDS document archive at the beginning of the Full-Scale System operation.

The document service model consists of two analytic phases. The first phase focuses on today's environment—the current request and ordering process, referred to as the current service model phase. The second phase focuses on the future—the projected DDS service, referred to as the DDS service model phase. By accurately depicting the current service model, reasonable assumptions can be made about the potential impact the DDS system will have on the existing STI Facility's Document Request Services, as well as, about the unique requirements DDS will necessitate in its own right.

4.1 Current Document Service Model Phase

The NASA/RECON online access system currently provides a method for remote users to place electronic orders for NASA-supported documents. Predominantly, they order the stock copy or paper reproduction forms of these documents. The DDS system is presently anticipated to have no impact on the microfiche subscription service. As explained in subsequent sections, not only will DDS potentially create new demand from increased functionality, but also it will impact the existing methods of reproduction and request processing at the central STI Facility.

4.1.1 Document Copies

The STI Facility produces the monthly Report on Facility Operations, which contains tabulated data on completed document requests. Table 4–1, the STI Facility document requests for calendar year (CY) 1989 (based on table 12 from the monthly Report on Facility Operations), gives the distributions for all STI Facility document requests completed in 1989. Note that this table is for all requests serviced by the STI Facility regardless of accession series. Also note that the requests for documents that cannot be met by stock copies are filled by a reproduction, if it is available, or a request for a reproduction of a stock copy.

Table 4–2, the NASA Technical Reports for CY 1989, which is based on table 16 in the monthly Report on Facility Operations, contains statistics about the completed document requests that are reproduced NASA Technical Reports only. This second table is a subset of the first two entries in the first table. It is estimated that approximately 95 percent of the stock copies supplied are NASA Technical Reports.

Table 4-1. STI Facility document requests for CY 1989.

TYPE OF REQUEST COMPLETION	DOCS.	PERCENT OF DOCS. REQUESTED	NUMBER OF PAGES PROVIDED	PERCENT OF PAGES PROVIDED	AVG. PAGES PER DOC. REQUESTED
Reproductions (HC)	12,000	45%	1,200,000	74%	121
Stock copies (SC)	9,500	31%	600,000	26%	60
Other requests	6,500	24%	N/A	N/A	N/A
TOTAL	28,000	100%	1,800,000	100%	N/A

Table 4-2. NASA Technical Report requests for CY 1989.

NTR REQUESTS	DOCS.	PERCENT OF DOCS. REQUESTED	NUMBER OF PAGES PROVIDED	PERCENT OF PAGES PROVIDED	AVG. PAGES PER DOC. REQUESTED
Reproductions (HC) ^a	5,900	40%	732,000	52%	124
Stock copies (SC) ^b	9,000	60%	675,000	48%	75
TOTAL	14,900	100%	1,407,000	100%	N/A

^a NASA Technical Report reproduction (HC) requests are extracted from table 16 of in all 12 of the STI Facility's monthly Report on Facility Operations for 1989.

^b NASA Technical Report stock copy (SC) requests are extracted from table 12 in all 12 of the STI Facility's monthly Report on Facility Operations for 1989.

4.1.2 STI Facility versus NASA Centers

The next step in the DDS quantitative service model is to separate the NASA Technical Report requests into two categories: requests that come directly to the STI Facility from users not associated with a NASA Center, and requests that come from and go to the NASA Centers. It is the latter group that is considered the prime candidate for remote communications to the DDS system. Again, relying mainly on table 16 of the monthly Report on Facility Operations, it is assumed that the reproduced NASA-supported documents strongly equate to NASA Technical Reports. This gives the breakdown shown in table 4-3, the central and remote site NASA Technical Report request origination for CY 1989. This table shows the number of requests that are considered to originate at the STI Facility and those that are considered remote NASA Technical Report document requests from a NASA Center.

The remote subtotal indicates the degree of requests at NASA Centers for NASA Technical Reports. These numbers are used as the starting point for making assumptions upon which to base some estimated figures for remote communications demand.

Table 4-3. Central and remote site NASA Technical Report request originations for CY 1989.

NTR REQUESTS BY REQUESTOR	NUMBER OF DOCS. REQUESTED	PERCENT OF DOCS. REQUESTED	NUMBER OF PAGES PROVIDED	PERCENT OF PAGES PROVIDED	PAGES PER DOC. REQUESTED
NASA Centers (HC)	3,400	40%	421,000	52%	124
NASA Centers (SC)	5,200	60%	390,000	48%	75
SUBTOTAL (remote)	8,600	58%	811,000	58%	N/A
STI Facility (HC)	2,500	17%	310,000	22%	124
STI Facility (SC)	3,800	25%	286,000	20%	75
SUBTOTAL (central)	6,300	42%	596,000	42%	N/A
TOTAL	14,900	100%	1,407,000	100%	N/A

While the DDS system is expected to provide improvements in quality, it is the dramatic improvement in turnaround time that will be a significant upgrade. When coupled with selective access to documents subparts as listed on the Table of Contents of that document, users will obtain precisely what they want faster than ever. Currently, using non-DDS methods, turnaround time for stock copy requested is three to five days or even longer for reproductions from microfiche or originals. DDS will provide same day, if not same hour, service; this is the reason that an anticipated diversion at significant levels is expected to occur. This type of request is the reason why counts for stock copy requests and reproductions from microfiche and originals are included in the DDS model. An average of 75 pages per stock copy document was assumed in order to calculate the stock copy page volume.

4.1.3 Summary of the Current Service Model Phase

Over the last few years, the level of NASA/RECON document requests have remained largely constant. Many factors can influence the document request level during the next decade, including the overall level of funding for NASA, NASA's emphasis on report production, NASA's research focus, and the availability of technical report literature.

4.2 DDS Service Model Phase

To characterize the Full-Scale System communications requirements properly and completely, three critical parameters need to be identified. The first is the estimated remote traffic volumes to be serviced by the DDS system. This volume is important to the Impact Analysis. In addition, this volume establishes a baseline for minimum communications criteria, below which would restrict DDS functionality. Section 4.2.1, *DDS Traffic Volume*, provides the model phase detail of the estimated remote traffic volume.

The second parameter is the bandwidth of the communications line that the application must use. Irrespective of traffic volumes, below a minimum transfer-rate level, an application's functionality and particularly its performance is restricted. Communications lines are available to service traffic at standardized transfer rates; section 5.1.1, *DDS Document Service Rates*, shows the services levels they will provide for DDS.

The third parameter is management of the stochastic variation of the document requests, specifically, the random nature of anticipated interactive remote access. Knowledge of the probabilistic variation of requests is necessary to size the bandwidth of the communications line wide enough to handle not only the volume of the remote traffic, but also its transient nature. Management of this stochastic variation will rely on a queuing model and simulation to address congestion and ways to avoid delays that this stochastic variation can cause.

4.2.1 DDS Traffic Volume

Projections are made regarding the amount of communications traffic expressed in pages, anticipated during the Full-Scale System, at the central site and at each of the 16 remote sites. These projections are based on a number of assumptions pertinent to the expected usage patterns of NASA Technical Reports using the new DDS on-demand, remote electronic access features. NASA/RECON usage patterns of NASA Technical Reports are assumed to be a good indicator of new DDS usage at the remote sites. NASA/RECON historical usage, extracted from table 16 of the monthly Report on Facility Operations, can be broken down into a statistical viewpoint comparable to the DDS remote site profiles.

4.2.1.1 Remote Site Usage Grouping

It is important to note that most of the 16 remote sites have different characteristics of NASA/RECON usage of NASA Technical Reports, depending on many changing factors such as level of funding for research activities and percentage of researchers using NASA/RECON. An almost linear shape of document ordering history exists for the remote sites based on 1989 data as described in section 4.1.1, *Document Copies*. The document ordering trend also could be affected by different data organization and analysis methods applied to the NASA/RECON historical usage. Assuming that the current data organization methodology is valid for grouping purposes, Table 4-4, the grouping of remote sites by NASA/RECON usage, presents a useful categorization of remote sites into three groups: large, medium, and small.

A case can be made for grouping LeRC into a separate group—very large—due to its enormous variance in relation to the other sites in the large group. For the purpose of estimating DDS remote traffic volumes, it will suffice to leave LeRC in the large group. The rationale for starting the medium group with RSIC is because of the relatively large gap between RSIC and the next largest NASA/RECON user, GSFC. The same

TABLE 4-4. Grouping of remote sites by NASA/RECON usage of NASA Technical Reports.

SITE GROUP	CENTER NAME	DOCUMENT REQUESTS (%)	CUMULATIVE REQUESTS (%)
Large	LeRC	23.6%	23.6%
	LaRC	14.3%	37.9%
	SSC	10.3%	48.2%
	HQ/LIB	9.1%	57.3%
	GSFC	8.9%	66.2%
SUBTOTAL		66.2%	N/A
Medium	RSIC	6.6%	72.8%
	JSC	6.3%	79.1%
	ARC	5.5%	84.6%
	MSFC	4.2%	88.8%
	JPL	3.8%	92.6%
	WTF	3.3%	95.9%
SUBTOTAL		29.7%	N/A
Small	KSC	1.7%	97.6%
	DRFC	1.0%	98.6%
	WFF	0.6%	99.2%
	GISS	0.4%	99.6%
	HQ/ADMIN	0.3%	99.9%
SUBTOTAL		4.0%	N/A

logic was applied to the first member of the small group, KSC. In table 4-5, the summary of remote site groupings, the groups are depicted in terms of size of the entire group and number of sites included in the group.

This summary allows the determination of an average size, percentage of total use per group, which will be used to refine the traffic projections to be discussed. The average size of a large remote site can be thought of as approximately 13 percent of the entire

TABLE 4-5. *Summary of remote site groupings.*

SITE GROUP SIZE	DOCUMENT REQUESTS BY GROUP (%)	NUMBER OF SITES PER GROUP	AVG. DOC. REQUESTS PER GROUP (%)
Large	66.2%	5	13.24%
Medium	29.7%	6	4.95%
Small	4.0%	5	0.67%
TOTAL	99.9%	16	N/A

remote site usage. The average size of a small remote site is approximately 5 percent. Another group not explicitly mentioned yet is the average site group, consisting of no real members but theoretically containing 16 average sites. The average size of an average site is 6.25 percent (1 divided by 16).

4.2.1.2 Annual DDS Traffic Projections

Based on the second table in section 3.1.5 on the estimated reproduction workload at the STI Facility, the estimated number of pages to be reproduced in the first Full-Scale System operational year is 927,000. This is a result of a 3-percent compounded growth rate for eight years from the 1989 figures of 732,000, found in the second table in section 4.1.1 on the NASA Technical Report requests for CY 1989. Year five of the Full-Scale System should result in 1,044,000 pages requested and reproduced. STI Facility staff assumed that 90 percent of the projected number of pages to be reproduced at the STI Facility will be generated by the Full-Scale System.

Another important component in the annual traffic projections is the number of stock copies to be delivered. It is assumed that 30 percent of the number of pages of stock copy requests will be satisfied by remote access to DDS. As per the second table in section 3.1.5, there should be 855,000 stock copy pages requested at the STI Facility during year one of the Full-Scale System and 962,000 in year five.

The third component in the DDS traffic projections is comprised of assumed additional traffic as a result of the nonsequential access capabilities within DDS. This component, referred to as "supplemental," is based on general assumptions about the user population and DDS applications. The supplemental number of pages in year one of the Full-Scale System is estimated at 1,988,039, and in year five, the figure is estimated at 2,000,744.

For the purposes of this Impact Analysis, the term “print volume” will refer to document printing at 300 dpi for 120 pages, unless specifically stated as “page print volume” (single page). Each of the three projection components have various subcomponents that correspond to a decomposition of the annual figures into the specific DDS transmission transaction types: document print, page print, and page view. Each of these transaction types can be qualified by location—central or remote site.

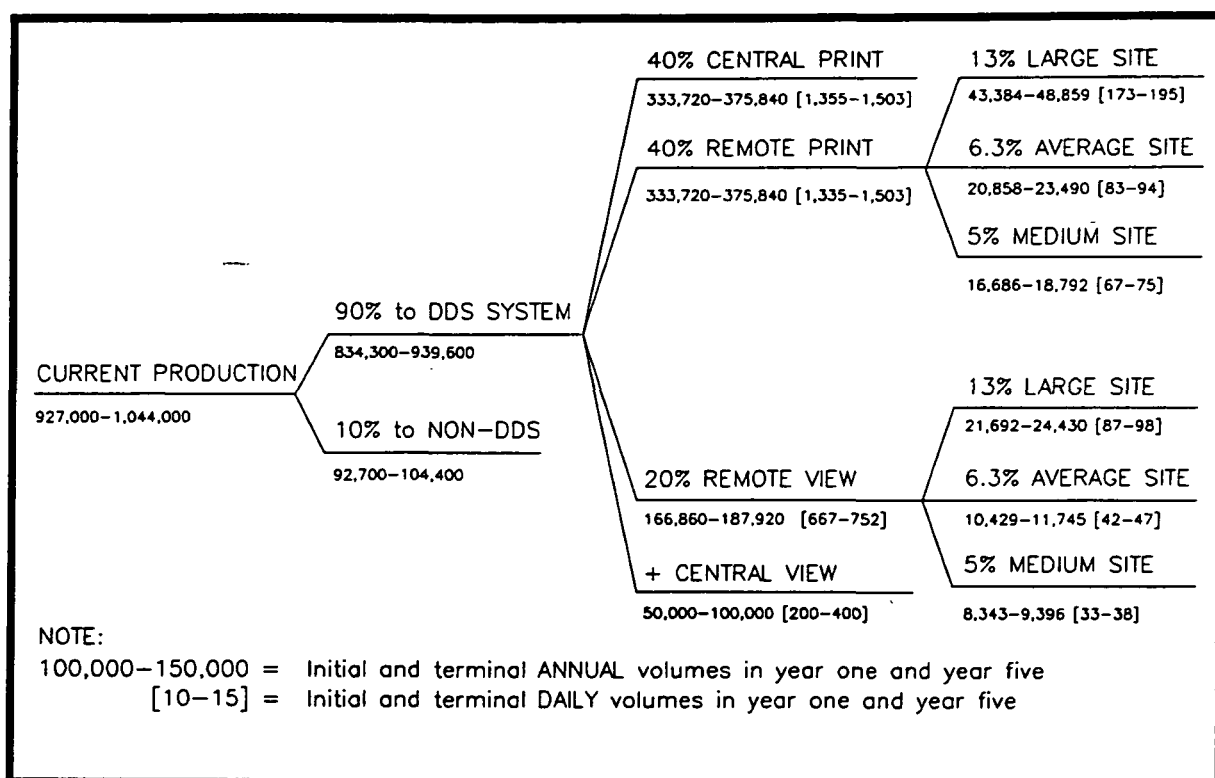
The assumed transmitted resolution for printing is 300 dpi—the standard laser printer output resolution level. The resolution for viewing a single page on the image display is 75 dpi (1/16th the amount required for a 300-dpi page). This viewing resolution is equivalent to VGA display quality (640 pixels across by 480 pixels down) and is assumed to be sufficient for most display applications. The imaging display has also been configured to support viewing resolutions as high as 150 dpi. Although there will be some 150 dpi transmissions, it is further assumed that the majority of transmissions will be either at 75 or 300 dpi. An assumed compression ratio of 10:1 is used for all image file size estimates.

A decision/volume tree has been prepared that decomposes the annual volume figures for reproduction, stock copies and supplemental requests into the above categories. Each branch in the volume tree is labeled with the assumed percentage of the total number of pages from the preceding branch along with the specific breakdown category. Under the branch label, the annual and daily traffic volume projections are provided; the daily figure is enclosed in brackets. When relevant, remote site group breakdowns are provided for site-level analysis. All traffic volume is expressed in terms of 8.5-by-11-inch black-and-white pages, the standard DDS image file unit.

4.2.1.3 *Reproduction Volume Tree*

Figure 4–2, the reproduction volume tree in pages annually and daily, represents the breakdown of annual reproduction requests into the DDS category and non-DDS category initially, and then the subcategories that are relevant to the reproduction component. All volumes are expressed as numerical ranges for years one through five of the Full-Scale System. The daily conversion factor is 250 days per year.

It is assumed that of the 90 percent of the current reproduction volume diverted to DDS, 40 percent will be printed at the central site and 40 percent will be printed at the remote sites, both ranging from 333,720–375,840 pages annually and 1,335–1,503 pages daily. The remaining 20 percent of the diverted current reproduction volume is allocated to remote viewing at 166,860–187,920 pages annually and 667–752 pages daily. This assumption allows for a percentage of the reproduction volume being viewed and then determined to be undesirable for printing. A separate branch on the reproduction volume tree represents the additional viewing activities at the central site that is antici-

Figure 4-2. Reproduction volume tree in pages annually and daily.

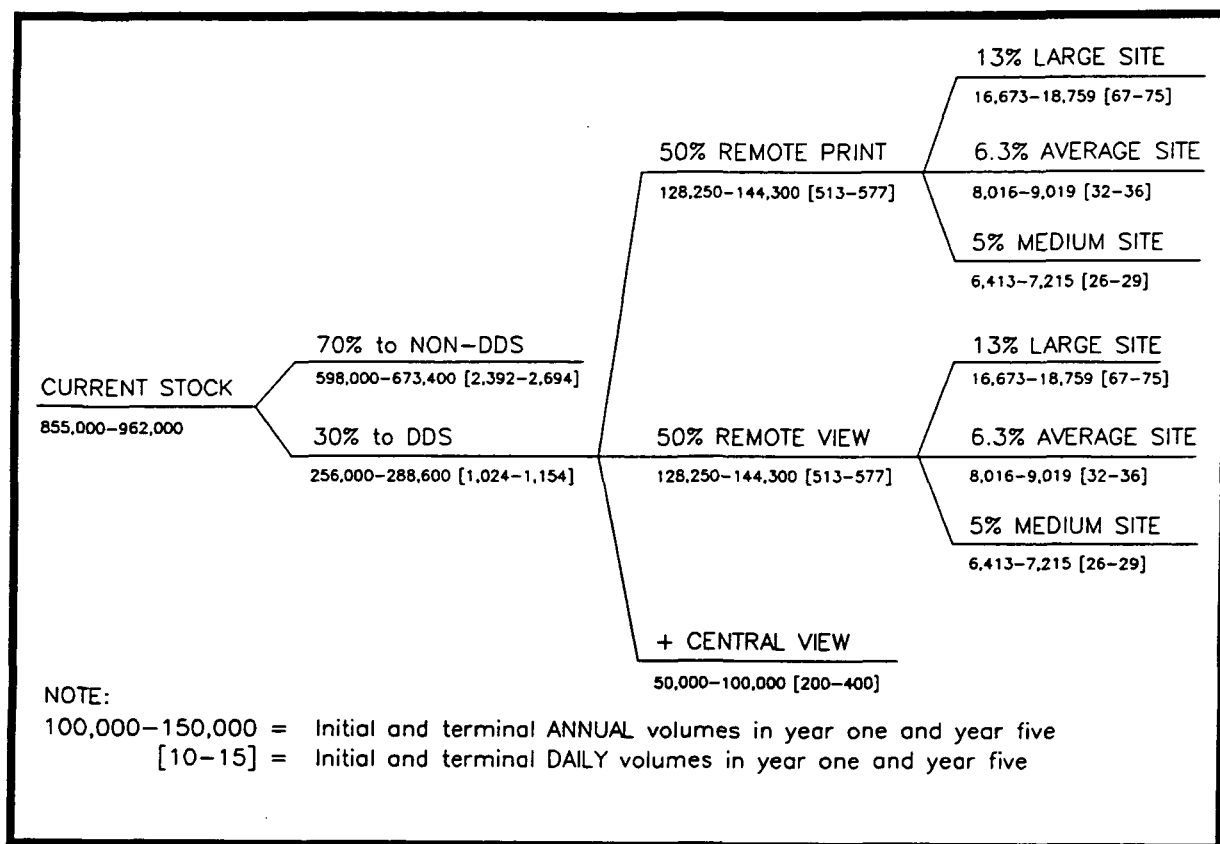
ated for support of the reproduction requests from requesters without remote access. The remote site volumes are broken down by single site groups as described in section 4.2.1.1, *Remote Site Usage Grouping*.

4.2.1.4 Stock Copy Volume Tree

In figure 4-3, the stock copy volume tree in pages annually and daily, the volume of pages associated with stock copy requests is represented along with the decomposition percentage assumptions.

Of the 30 percent diverted pages to DDS, 50 percent is expected to be printed remotely and 50 percent are expected to be viewed without printing at all. No percentage of stock copies will be diverted at the central site because existing stock copies are expected to be available and are assumed to be more desirable. An additional volume estimate has been included to take into account viewing at the central site to support the stock copy document request processing activities. Remote site volumes are provided where applicable.

Figure 4-3. Stock copy volume tree in pages annually and daily.



4.2.1.5 Supplemental Volume Tree

The supplemental volumes are based on speculation regarding the remote access scenario pertaining to use by a research scientist or engineer. It is envisioned that the user would browse through various sections of documents of interest (where bibliographic references to documents are retrieved during a NASA/RECON search session). The total amount of time allocated for this interactive activity is assumed to be two hours per day per large remote site. At five pages viewed per minute—a reasonable amount of time for quick reading—the user could browse through 300 pages on the DDS workstation display. Two hours of viewing results in 600 pages at this rate. It was also assumed that 25 percent of the viewed pages (150 pages per day) would be printed page by page. From the communications traffic perspective, each page that needs to be transmitted must be identified. Since the viewing resolution of 75 dpi is insufficient for most page printing, it is assumed that another transmission at 300 dpi will be required to support the extra 150 pages per day. Refer to table 4-6, the estimated supplemental annual and daily volumes at a large remote site in pages, for the volume projections from years one through five of the Full-Scale System. Included in this table are the document printing estimates based on current local microfiche blowback reproduction

pages at LeRC. The DDS archival percentage (ARC%) for Full-Scale System years is extracted from the second table in section 3.1.5, *Reproduction Workload at the NASA STI Facility*.

TABLE 4-6. Estimated supplemental annual/daily volumes at large remote site in pages.

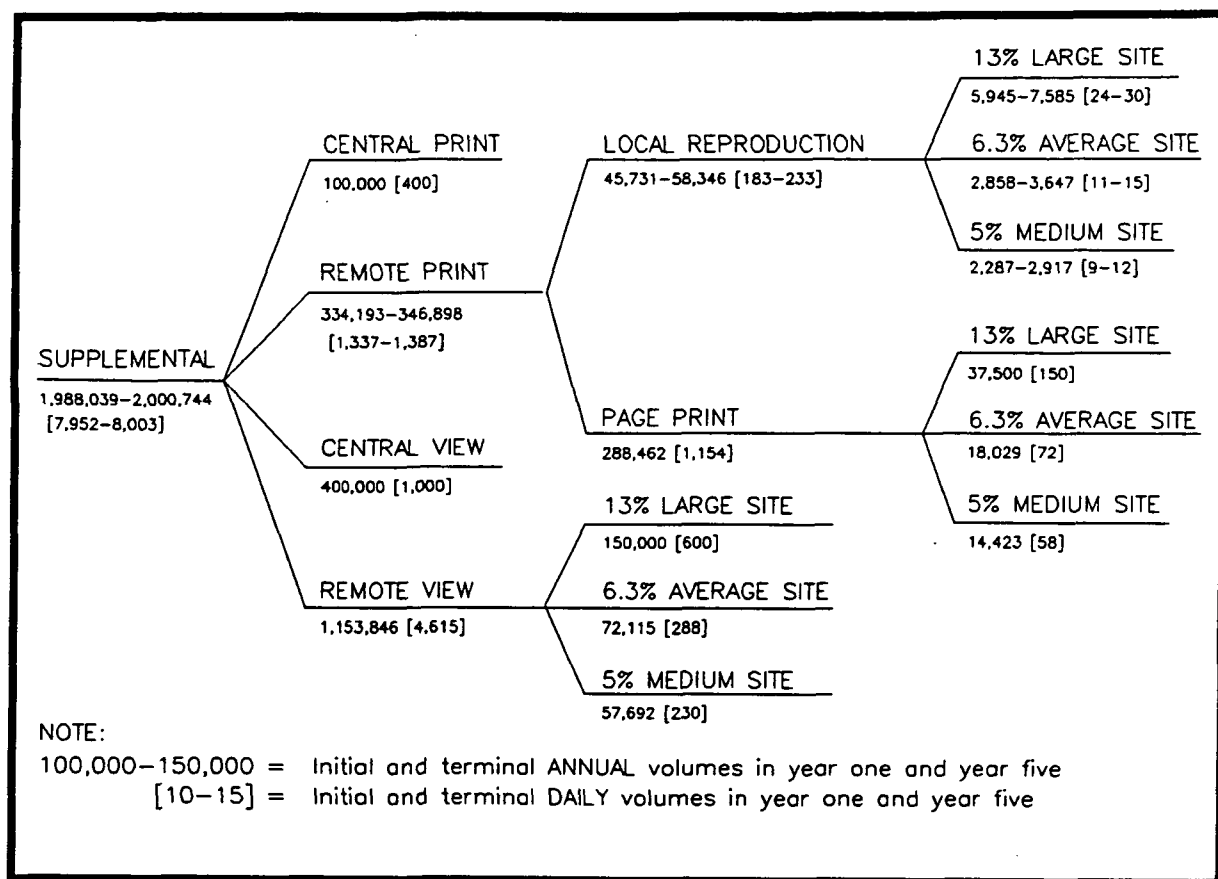
CAL. YEAR	PILOT YEAR	F-S YEAR	DDS ARC%	ANNUAL			DAILY		
				VIEW	PAGE PRINT	DOC. PRINT ^a	VIEW	PAGE PRINT	DOC. PRINT ^a
1997	Six	One	58%	150,000	37,500	5,945	600	150	24
1998	Seven	Two	61%	150,000	37,500	6,253	600	150	25
1999	Eight	Three	65%	150,000	37,500	6,663	600	150	27
2000	Nine	Four	69%	150,000	37,500	7,073	600	150	28
2001	Ten	Five	74%	150,000	37,500	7,585	600	150	30

^a Only local reproduction that replaces local microfiche blowback is considered in light of DDS archival percentage (ARC%).

The supplemental volume tree is depicted in figure 4-4 and encompasses additional viewing and printing at both the central and remote sites. The table in this section is the basis for the low-level page volume estimates in the figure in this section.

This tree is different from the two previous trees in that volume estimates were generated from the lowest level branches in the tree and projected upwards (to the left) to produce the summary figures.

Figure 4-4. Supplemental volume tree in pages annually and daily.



4.2.2 Summary of DDS Service Model Phase

The three volume trees have been summarized by remote site group and all remote sites in table 4-7, the summary of daily volumes by location and group in pages. This table excludes the primary reproduction volume from requestors without remote access, as projected in the second table in section 3.1.5 on the estimated reproduction workload at the STI Facility.

TABLE 4-7. Summary of daily volumes by location and group in pages.

REMOTE SITE GROUP	DOC. PRINT		PAGE PRINT		VIEW		ALL PAGES	
	YEAR ONE	YEAR FIVE	YEAR ONE	YEAR FIVE	YEAR ONE	YEAR FIVE	YEAR ONE	YEAR FIVE
Large:								
Reproduction	173	195	0	0	87	98	260	293
Stock	67	75	0	0	67	75	134	150
Supplemental	24	30	150	150	600	600	774	780
SUBTOTAL	264	300	150	150	754	773	1,168	1,223
Medium:								
Reproduction	67	75	0	0	33	38	100	113
Stock	26	29	0	0	26	29	52	58
Supplemental	9	12	58	58	230	230	297	300
SUBTOTAL	102	116	58	58	289	297	449	471
Average:								
Reproduction	83	94	0	0	42	47	125	141
Stock	32	36	0	0	32	36	64	72
Supplemental	11	15	72	72	288	288	372	375
SUBTOTAL ^a	127	145	72	72	362	372	561	588
All 16 sites:								
Reproduction	1,335	1,503	0	0	667	752	2,002	2,255
Stock	513	577	0	0	513	577	1,026	1,154
Supplemental	183	233	1,154	1,154	4,615	4,615	5,952	6,003
SUBTOTAL ^a	2,031	2,314	1,154	1,154	5,796	5,944	8,980	9,412
Central site:								
Reproduction	1,335	1,503	0	0	200	400	1,535	1,903
Supplemental	0	0	0	0	200	400	200	400
SUBTOTAL ^a	1,335	1,503	0	0	400	800	1,735	2,303
GRAND TOTAL ^a	3,366	3,817	1,154	1,154	6,196	6,744	10,715	11,715
^a Minor differences in totals between this table and other tables can be attributed to rounding variations in the spreadsheets used to calculate the numbers.								

The total number of pages by transmission transaction types for the average site is of the most interest, in terms of service rates, to the system queuing model used in section 5.1.2, *DDS Arrival and Service Distributions*. The totals for all 16 remote sites, based on the average site volumes, will indicate the communications traffic load at the central site facility. For a normal distribution of the page volumes over an 8-to-12-hour period, the central site capacity will be planned to include a configuration of appropriate system size. From the individual remote site, specific communications requirements could be determined, based on the site group page volumes.

In table 4-8, the summary of remote site daily volumes in pages and megabits, the site groups and the aggregate of all sites are represented in terms of number of pages transmitted per day and the corresponding transmission load in number of million bits of data, or megabits (Mb).

TABLE 4-8. Summary of remote site daily volumes in pages and megabits.

REMOTE SITE GROUP	DOC. PRINT		PAGE PRINT		VIEW		PAGES/Mb	
	YEAR ONE	YEAR FIVE	YEAR ONE	YEAR FIVE	YEAR ONE	YEAR FIVE	YEAR ONE	YEAR FIVE
NUMBER OF PAGES								
Large	264	300	150	150	754	773	1,168	1,487
Medium	102	116	58	58	289	297	449	573
Average	127	145	72	72	362	372	561	588
All 16 sites	2,031	2,314	1,154	1,154	5,796	5,944	8,980	9,412
SIZE IN MEGABITS ^a								
Large	222.2	252.5	126.2	126.2	39.7	40.7	388.0	419.3
Medium	85.8	97.6	48.8	48.8	15.2	15.6	149.8	162.0
Average	106.9	122.0	60.6	60.6	19.0	19.6	186.5	202.2
All 16 sites	1,709.1	1,947.2	971.1	971.1	304.8	312.6	2,985.0	3,230.9
^a View pages are transmitted at 75 dpi (52,594 bits per page). Printed pages are transmitted at 300 dpi (841,500 bits per page). Both page sizes were calculated using an image compression ratio of 10:1.								

The estimated traffic for a large site is in excess of 400Mb per day. An interesting contrast is the daily traffic estimate for the NASA/RECON online application, approximately 240Mb, as shown in the following equation:

$$240Mb = \frac{15,000 \text{ RECON commands}}{\text{day}} \times \frac{2,000 \text{ characters}}{\text{command}} \times \frac{8 \text{ bits}}{\text{character}}$$

A single large group DDS site exceeds the daily NASA/RECON traffic volume. In addition, the total daily DDS remote site traffic volume might exceed NASA/RECON by an order of magnitude or more than 13 times. Another contrasting point is that DDS traffic is comprised of large files intermittently transmitted throughout the day, whereas NASA/RECON transmitted data is comprised of much smaller files and transmitted at a more constant rate throughout the day. In other words, DDS is like rush-hour traffic and NASA/RECON is like steady-stream traffic.

5-REMOTE COMMUNICATIONS ANALYSIS

In section 4-*DOCUMENT SERVICE ANALYSIS*, an analysis of the current document request service was presented as the first phase in a conceptual model of document service. In this section, the quantitative model of current service is extrapolated for the purpose of projecting the estimated DDS service levels as specified in the second phase of the document service model—the most critical element in properly sizing the DDS remote communications requirement.

5.1 DDS Capacity Planning

In assessing the remote communications requirement, general characteristics of image transmission are discussed in addition to specific assumptions regarding DDS image traffic and the subsequent ramifications to the assumed DDS network design in terms of capacity planning and expected performance levels.

5.1.1 DDS Document Service Rates

Assuming a document volume flow workload provides a basis for determining specifications for remote image communications. Volume flow does not reveal the basic relationship between available communications services and what that means for the instantaneous behavior of an application such as the remote transmission of image pages. The minimal image situation is the remote transmission of one compressed page at a particular resolution over a communications line rated at some number of bits per second. This functional relationship gives a method to calculate a page-service rate or time. This time equals the communications data-transfer rate divided by the sum of the number of bits per page (compressed) plus any overhead. Table 5-1, the approximate single-image, page-service levels per page, gives the basic service rates per page.

Table 5-2, the approximate image document service levels per document, gives the basic rates for an average NASA Technical Report of 120 pages in length.

Table 5-1. Approximate single-image, page-service levels per page.

COMMUNICATIONS LINE TRANSFER RATES ^a				
RESOLUTION/ IMAGE TYPE	MODEM (9.6 Kbps)	LEASED LINE (56 Kbps)	ISDN ^b (128 Kbps)	T1 ^c (1.544 Mbps)
300 dpi Halftones	90 sec. Very slow	17 sec. Slow	8 sec. On-demand	≤ 2 sec. Interactive
150 dpi Line art	22.5 sec. Slow	6 sec. On-demand	3 sec. Interactive	≤ 1 sec. Interactive
75 dpi Serif type	8 sec. On-demand	3 sec. Interactive	≤ 1 sec. Interactive	≤ 1 sec. Interactive
37.5 dpi Sans-serif type	3 sec. Interactive	≤ 1 sec. Interactive	≤ 1 sec. Interactive	≤ 1 sec. Interactive
^a With regards to the user viewing a document page, subjective terms have been applied to the speed at which images are transmitted: "very slow" means an unacceptable delay; "slow" means a noticeable delay; "on-demand" means reading speed; and "interactive" means faster than reading speed. ^b Integrated Services Digital Network (ISDN) basic service uses 2 lines, rated at 64 Kbps, and primary service is 23 lines, rated at 64 Kbps (comparable to T1). Effective throughput is estimated at 75 percent, or 96 Kbps. ^c T1 is the equivalent of 24 lines, rated at 64 Kbps.				

Table 5-2. Approximate image document-service levels per document.

COMMUNICATIONS LINE TRANSFER RATES ^a				
RESOLUTION/ IMAGE TYPE	MODEM (9.6 Kbps)	DIGITAL (56 Kbps)	ISDN (128 Kbps)	T1 (1.544 Mbps)
300 dpi Halftones	3 hrs. Next day	34 min. Same day	16 min. On-demand	≤ 1 min. Interactive
150 dpi Line art	46 min. Same day	12 min. On-demand	6 min. Interactive	≤ 1 min. Interactive
75 dpi Serif type	16 min. On-demand	6 min. Interactive	≤ 1 min. Interactive	≤ 1 min. Interactive
37.5 dpi Sans-serif type	6 min. Interactive	≤ 1 min. Interactive	≤ 1 min. Interactive	≤ 1 min. Interactive
^a With regards to the user requesting a document page (average number of pages per document is 120), subjective terms have been applied to the speed at which the request is fulfilled: "next day" means sent when scheduled (if scheduled early in the day and the system is not too busy, the request could receive "same day" service); "same day" means several hours; "on-demand" means reading speed; and "interactive" means faster than reading speed.				

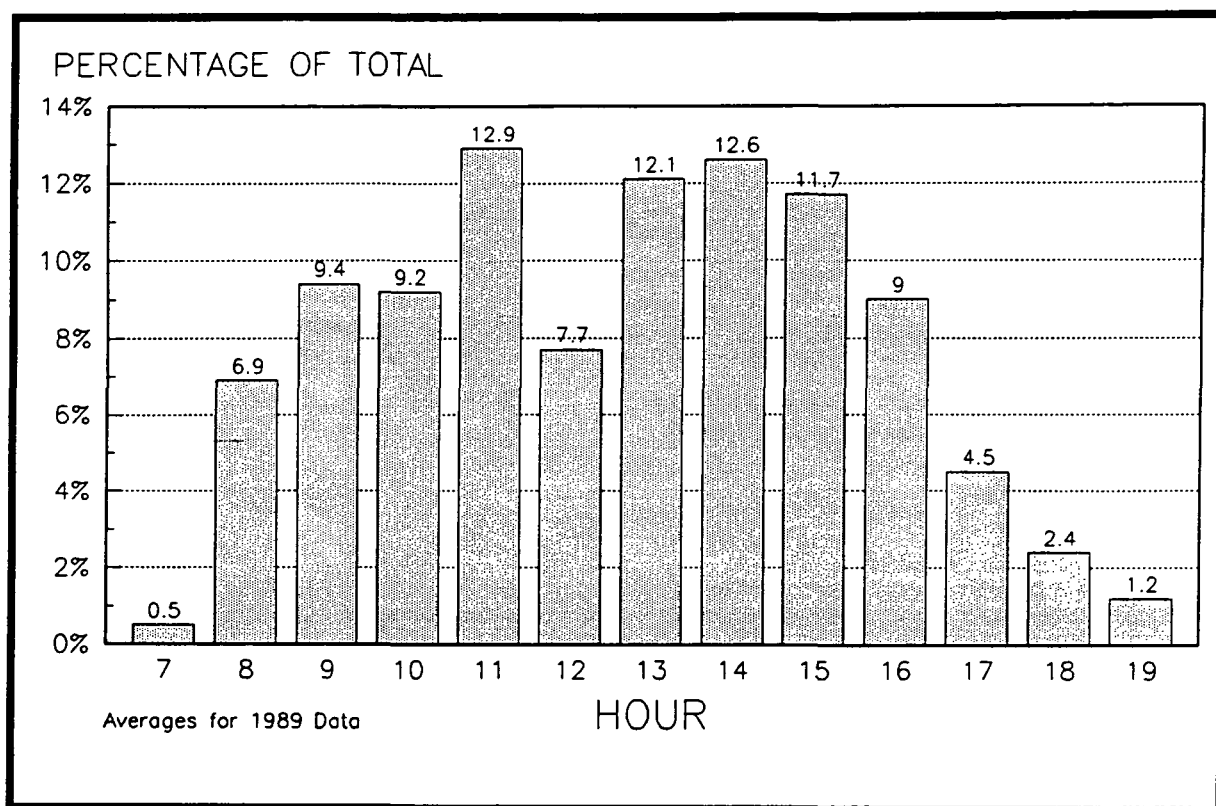
The data-transfer rate is a key concept to measure a system or device's ability to perform the work of data transport. Of all the components that comprise a computer system such as the DDS system, it is the communications service that offers the lowest performance/price ratios. Even the 16-bit AT computer bus can sustain a data-transfer rate of over 1 Mbps (near T1 levels). Optical drives and LANs, which are considered slow devices, can sustain rates 10 times higher than this. If the remote access component is to be functionally valued as an integral and significant part of the DDS system, then the optimization of the communications performance will provide considerable rewards and savings.

It is suggested that 75 dpi be evaluated for suitability for remote viewing of images (when reading the document page for content) in that it appears a majority of NASA Technical Report material appears to consist of pages of text with either tables of text or line art. Remote printing of documents is still recommended at the maximum scanned and stored resolution to present the highest quality available, representing the original intent of the author.

5.1.1.1 Document Requests by Hour of Day

The online search and order system—NASA/RECON—allows users at NASA Centers to order copies of documents electronically. These requests for documents are received and processed at the STI Facility. The information about the request is saved in computer files.

Some preliminary analysis was performed on current NASA/RECON document request rates and distributions from the saved computer files. While there is some variation by day of week and month of the year, these are well within estimated parameters that need to be attained to provide adequate reserve utilization to meet time of day demands. The time of day distribution requests are important in deriving expected arrival means and their variance. Figure 5-1, the NASA Technical Report requests ordered through NASA/RECON per hour, gives a percent basis of these distributions.

Figure 5-1. NASA Technical Report requests ordered through NASA/RECON per hour.

5.1.1.2 Documents and Pages by NASA Center

The current computer systems at the STI Facility do not provide an integrated and comprehensive audit of requests for documents on a transaction basis. Preliminary analysis was performed in an attempt to rectify, on a transaction basis, information captured in communications files with document request history files. The effort to complete this analysis subtask effectively was judged to be beyond the scope of this Impact Analysis task. Therefore, sufficient data in both quantitative and qualitative terms is not available to reconcile all quantities and how they can be cross-tabulated. Table 5-3, the NASA Technical Reports reproduced by NASA Center during CY 1989, gives the current activity by NASA Center in descending activity for reproduced copies of NASA Technical Reports.

Equally illuminating is figure 5-2, the NASA/RECON NASA Technical Report requests, by NASA Center, which breaks down the requests by each NASA Center. Both the figure and table in this section show a wide variation in request demand. It should be carefully noted that this table reflects only the demand that is actually seen at the STI Facility. Significant quantities are locally reproduced at each NASA Center

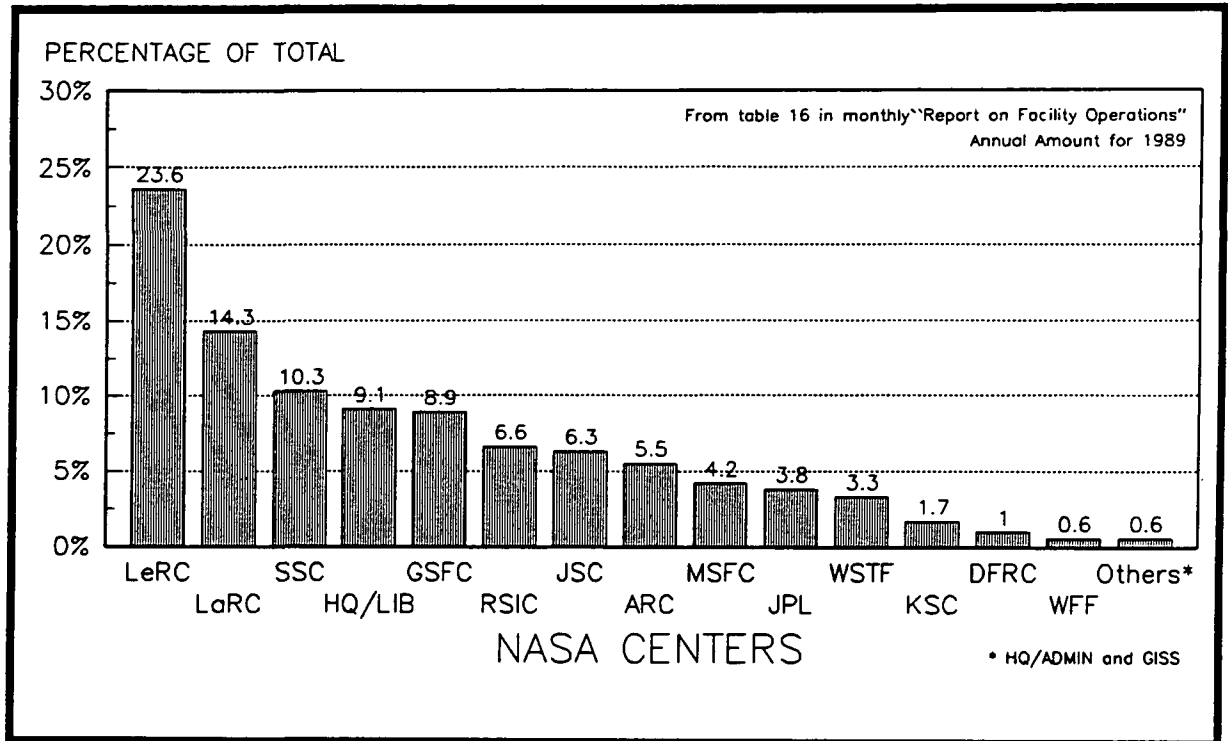
Table 5-3. NASA Technical Reports reproduced during CY 1989, listed by NASA Center.

NASA CENTER	NUMBER OF DOCUMENTS	PERCENT OF DOCUMENTS	NUMBER OF PAGES	PERCENT OF PAGES
LeRC	804	23.6%	87,318	20.7%
LaRC	488	14.3%	66,041	15.7%
SSC	352	10.3%	27,123	6.4%
HQ/LIB	311	9.1%	35,508	8.4%
GSFC	302	8.9%	38,303	9.1%
RSIC	223	6.6%	47,400	11.2%
JSC	213	6.3%	30,653	7.3%
ARC	186	5.5%	25,861	6.1%
MSFC	142	4.2%	28,558	6.8%
JPL	130	3.8%	14,077	3.3%
WTF	114	3.3%	6,816	1.6%
KSC	58	1.7%	5,118	1.2%
DFRC	35	1.0%	3,210	0.8%
WFF	22	0.6%	1,373	0.3%
GISS	15	0.4%	2,045	0.5%
HQ/ADMIN	9	0.3%	1,980	0.5%

both by library employees as well as patrons. This demand, which is currently being satisfied by local NASA Technical Report collections at the NASA Centers, stands to benefit from a DDS system.

Additional analysis is required to determine how the needs of each NASA Center can be best met in the short and long terms. One can surmise that as NASA funding changes, so will the document request needs of the NASA Centers. One should be very hesitant about grouping NASA Centers together. Their requests for document services are as varied as their missions. Any specifications or requirements for a network will have to take NASA Center needs and spatiality into account for an acceptable configuration. This type of analysis is appropriate for the recommended communications requirements analysis.

Figure 5-2. NASA Technical Report requests ordered through NASA/RECON, by NASA Center.



5.1.2 DDS Arrival and Service Distributions

The preceding analysis has been performed in order to estimate what the service load of the remote sites will be on the communications service at the central facility. This section will estimate some arrival and service means by type of request. Communications can then be approximately sized when one knows how frequent are the requests for documents/pages and how much time it will take to dispatch them by type.

The first column of table 5-4, the remote NASA Center estimated request rates by type, contains the results for an average remote site (taken from the first table in section 4.2.2, which dealt with a summary of the daily volumes by type and group size).

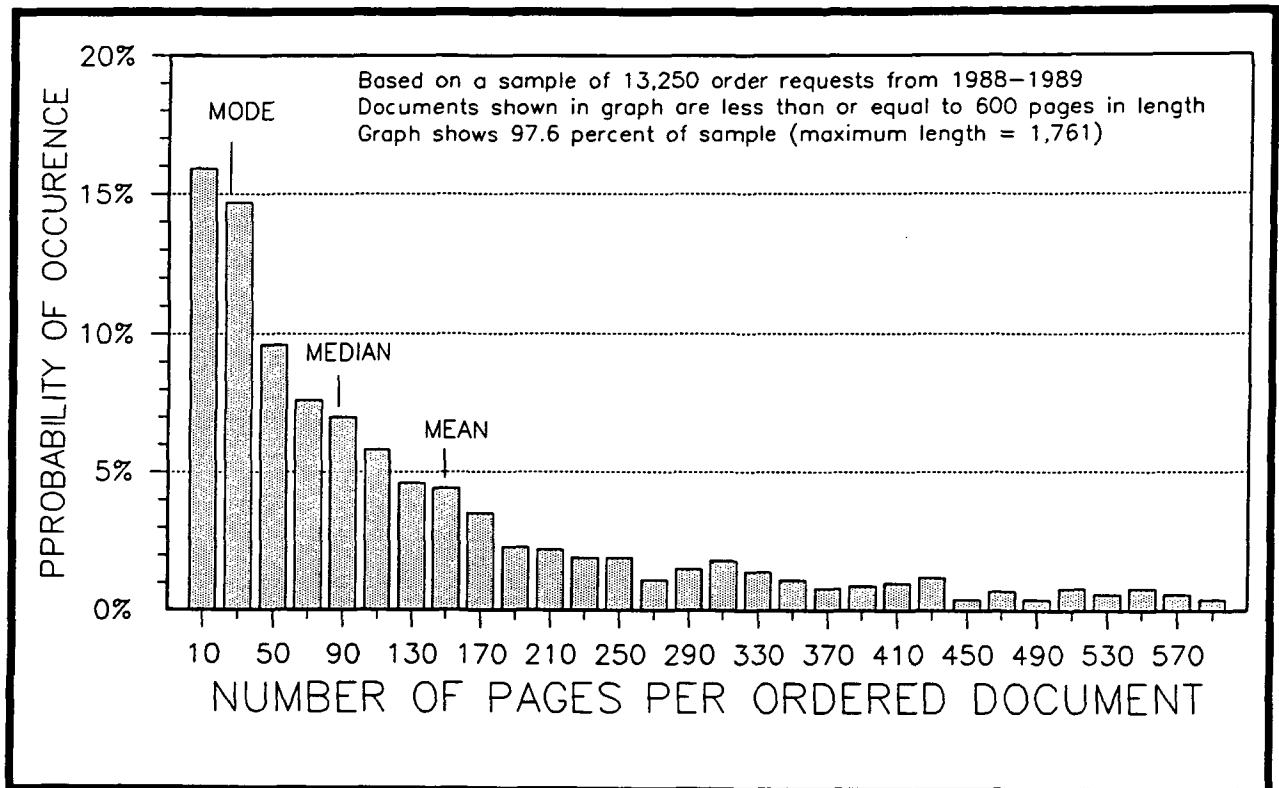
Table 5-4. Remote NASA Center estimated request rates by type.

TYPE OF REQUEST	PAGES PER DAY PER CENTER	PAGES PER DAY, ALL SITES	PAGES PER HOUR, ALL SITES	PAGE XMIT TIME (96 Kbps)	XMIT TIME PER HOUR
Print doc.	145	2,320	193	8 sec.	1,544 sec.
View page	371	5,936	495	0.5 sec.	248 sec.
Print page	72	2,592	95	8 sec.	760 sec.
TOTAL	588	10,848	693	16.5 sec.	2,552 sec.

The third column in the table above represents the total requests as an average value (in pages per hour) for all 16 remote sites. It is assumed that the Full-Scale System will process requests for documents as a multiple request for independent pages. An internal priority scheme will assume that viewing by page is at least as important as, if not more important than, printing by page. The combined page requests amounts become the arrival rates for requests for pages. The transmission (XMIT) time per page is based upon a 300-dpi print page compressing to an average of 96 kilobyte (KB) effective throughput, and a 75-dpi page being compressed 6KB (1/16th the size of a 300-dpi page) at an effective rate of 96 Kbps. The last column in the table above gives the total time in seconds per hour (out of 3,600 seconds). This value is calculated by multiplying the average number of pages by the transmission time per page.

An additional simulation component is the characterization of the distribution of the queue server service time. An important step in this direction is shown in figure 5-3, an analysis of NASA Technical Report requests ordered through NASA/RECON. These page length distributions and their associated probabilities can be incorporated into a simulator model to generate theoretical distributions that will closely approximate real world activity. Once the distributions of image compressions are known, most of the major inputs are in place to model the proposed DDS remote communications system activity.

These estimated values, while no substitute for a simulation with a properly complete model, do allow some approximated conclusions. If the bandwidth of the communications line were cut in half—the 48 Kbps effective value of a 56/64 Kbps communications line—there would be more to transmit than time to do it. Clearly, this is an unacceptable solution. The DDS steady-state, no-random model is already at 71-percent utilization with probably inadequate reserve to handle peaks without introducing serious delays. It appears

Figure 5-3. Analysis of NASA Technical Report requests ordered through NASA/RECON.

that at least two 56 Kbps lines or one Basic Rate Interface (BRI) ISDN line will be required from the STI Facility to PSCN. This estimated central site bandwidth requirement might actually increase to four or six 56-Kbps lines due to stochastic variations described in section 4.2, *DDS Service Model Phase*, and PSCN effective throughput rates.

Two possible solutions can make the DDS remote communications component serviceable with a 56/64 Kbps bandwidth. Note that the ratio of time spent transmitting a page at 300 dpi is still 10 times greater than the time spent transmitting low-resolution (75 dpi) viewing pages. If all requests for remote transmission of entire documents were queued nightly, this would be sufficient, albeit with some sacrifice in functionality. Another alternative is to reduce the resolution of the remotely transmitted pages for printing. The average resolution would have to be decreased from 300 dpi to below 200 dpi.

5.1.3 DDS Network and LAN Simulation

The arrival of these requests at the central STI Facility DDS system are probabilistic events best studied by computer simulation. Analytical methods are used to build deterministic models and therefore are not sufficient for building the required nondeterministic model. When requests for service occur faster than they can be dispatched, due to the restrictions of a finite bandwidth, congestion and delay inevitably are caused. The usual way this is han-

and services—and derive an optimal solution based on constraints giving the functional trade-offs between queue length, queue probabilities, number of servers, communications line bandwidth, and utilization factors.

Communications problems, such as queue length, wait probabilities, utilization factors, and system throughput, do not have cookbook algebraic solutions but are solved with the well-developed discipline of simulation and with significant amounts of computer time. It cannot be too strongly emphasized that such a study be performed unless one has access to essentially unlimited bandwidth, project funds and processing power. As little as complex communications systems lend themselves to ready-made estimated solutions, image transmissions, as proposed in the current DDS project, lend themselves even less.

5.2 Remote Communications Methods

This section will use the analysis and assumptions of the preceding sections and will determine the appropriateness of standardized communications methods and services for the DDS system remote communications needs.

5.2.1 Current Status

The DDS staff is assuming that PSCN will provide adequate communications service to NASA Headquarters Code NTT to support access to the central DDS system for all 16 remote sites. It is assumed that this service will not have significant direct costs to Code NTT, and that PSCN will incorporate and make available technological advances as they become available.

5.2.1.1 *Service-Level Transfer Rates*

As stated in section 5.1.2, the anticipated initial communications traffic load will warrant a service-level transfer rate of at least the 56–64 Kbps range, if not a multiple thereof, to maintain the DDS application functionality as currently envisioned. While this traffic is assumed to consist of several traffic rates and levels (see the first two tables in section 4.1.1, *Document Copies*), the DDS remote image application is best characterized as sporadic, but very large, interactive file transfers. Most remote computer-originated communications and, therefore, the networks that serve them, are still oriented to multiuser online transaction processing (OLTP). The only shared characteristic that OLTP has with the assumed DDS requirement is the desired interactive functionality. This perspective is critical. Just because the base transfer rate of a communications system (whether a local or wide-area network) appears to be adequate in a steady-state, batch type model, does not necessarily imply suitability for the transient nature of the proposed DDS Full-Scale System implementation.

5.2.2 Existing Solutions

For considering remote DDS traffic and developing a recommended solution, the following factors must be applied:

1. The remote transmission of a high volume of compressed images is an uncommon application. Few off-the-shelf solutions would be acceptable.
2. In a recent review of commercial off-the-shelf software and hardware offerings, the DDS staff has identified few instances of medium bandwidth (56–64 Kbps) connectivity to PC workstations where one task uses the entire bandwidth.
3. The few instances of existing applications are either fax-like, requiring the manual intervention of sending one page at a time, which is totally inappropriate for a document of several hundred pages, or use prohibitively expensive multiple-bandwidth equipment and services that go beyond the scope of the proposed DDS system.

These factors do not suggest that solutions to remote access to the DDS system is impractical, just limited in number. Most of the components are readily available, both software and hardware, at desirable performance/cost ratios. However, it will take a concerted systems engineering approach to make it work.

5.2.2.1 *Program Support Communications Network*

In accordance with NASA Headquarters direction, the DDS staff concurs that the Program Support Communications Network (PSCN) appears to provide the communications services that can support the DDS remote access functionality of the Full-Scale System. A stand-alone solution of one or more 56 Kbps circuit-switched communications lines would provide an acceptable bandwidth. It is not likely that PSCN can provide this level of service but rather DDS will have to share PSCN's X.25 packet-switched data service. This specific implementation of the DDS remote access application is of some concern with regard to the desirability and suitability of sharing the NASA packet-switched system. STI Facility staff wants the DDS system to be a well-behaved participant on PSCN if the requirements for participation are practical for all concerned. It is unlikely, however, that such participation is feasible. The DDS staff recommends that an appropriate communications requirements analysis be performed to determine facts about planned PSCN services.

5.2.2.2 *Analog Modem*

From the DDS remote access perspective, modems are limited transfer rate devices that simply do not have the performance for the kind of Full-Scale System service that is assumed will be delivered. The two tables in section 5.1.1, *DDS Document Service Rates*, provide some response levels for a single-user modem situation. Add to these

already slow times some relatively insignificant multiple NASA Center demand, and the response would rapidly deteriorate. While connection to the DDS system via analog modems might be provided as a stand-alone service to those users who are unable to access better communications equipment, analog modems are unable to handle the estimated demand DDS would place on them. Therefore, they cannot be recommended. It can be assumed that their current popularity will have less influence in the future as digital technologies are expanded as a separate services rather than sharing the analog circuits of voice telephone.

5.2.2.3 *Integrated Services Digital Network*

Many federal agencies are a year away from General Services Administration's (GSA) mandated transition to Integrated Services Digital Network (ISDN). The DDS staff assumes that it is highly likely by the start of the Full-Scale System that NASA Centers and the STI Facility will also be required to use this contracted communications service within the PSCN family of NASA communications services. Leading industry experts recommend that government network equipment purchased for use beyond three-to-five years (such as the Full-Scale System) should comply with ISDN.

Hayes Microcomputer Products recently joined a half-dozen other companies in producing an ISDN adapter for the PC. Industry analysts take this as a tacit admission that analog modem usage will be much less prevalent in the future than it is today.

It is with particularly strong optimism that the DDS staff favorably view the possibility of ISDN. Unlike most digital services of 56/64 Kbps or faster, ISDN is being aimed squarely at high-performance PCs and their applications, such as DDS remote access. If it is cost effective, and in all likelihood initial tariffs indicate it will be, the ISDN BRI service of 64 Kbps will provide an elegant, one-board solution that is inherently multi-tasking and have the highly desirable bandwidth of 128 Kbps. The design of ISDN allows for functionality and performance improvements. As an example, ISDN's out-of-band signaling (a separate 16-Kbps channel) has a claimed call set-up time of 3 seconds instead of the current in-band method of 20 seconds or more. This is a direct reduction in the time to view the first page of a DDS document on a circuit-switched system.

DDS staff recommends careful monitoring of this federal government move to ISDN and further exploration of the capabilities of this technology, as applicable to the DDS remote access system. DDS staff is awaiting PSCN technicians' view on this subject and how they feel the DDS system fits into PSCN and the needs of NASA users.

5.2.2.4 *Wide Bandwidth*

Beyond 56/64 Kbps lines is the world of fractional T1, T1 (1.544 Mbps), and even multiple-bandwidth lines. These circuits are costly but provide high transfer rates for demanding applications. ISDN also has the functional equivalent of a T1 line, called a Primary Rate Interface (PRI) service. This service consists of 23 BRI service channels plus a control channel. Examples that use this wide bandwidth service include mainframe-to-mainframe communication, televideo-conferencing, and specialized applications, such as digital images from space satellites. An increasing number of private and government agencies that have applications similar to DDS are choosing a T1 line. These applications include the remote transmission of documents (not just an occasional single page) of digital images at 300 dpi.

The long distances between many NASA Centers makes the current prices for wide bandwidth service prohibitive. Even PSCN provides this service only to the highest level of customer need and priority. Still, T1 is a commodity that is traded and contracted for in the marketplace and requires monitoring in the future when more reasonable prices would increase its attractiveness for the DDS system.

5.2.3 **Future Solutions**

Considering the advancements in microcomputers during the last decade, the future of wide-scale remote communications is bright, even considering the aforementioned restrictions. New and innovative applications require new solutions. Not surprisingly, today's networks and protocols are generally inadequate. They exist to solve problems different from those caused by the need for DDS remote access.

Innovation needs to be built into contracts to provide features that will take advantage of technology development. Network technology is expected to experience some significant changes in the next 3 to 10 years. Those contracts that can remain flexible and take advantage of the way technology advances solutions will be the clear winners.

6-FULL-SCALE SYSTEM IMPACTS

In section 4-*DOCUMENT SERVICE ANALYSIS*, the document service requirements and capacity planning impacts were discussed using quantitative methods. In this section, impacts to existing equipment, personnel, and services are described. New equipment and services are identified as a result of the Full-Scale System implementation. Minor reduction to the current staffing levels are also discussed.

6.1 Equipment

A variety of impacts to existing and new equipment at the central facility and remote sites are presented below.

6.1.1 STI Facility

Impacts to the STI Facility DDS equipment configuration are discussed in terms of existing equipment and new components.

6.1.1.1 *Impacts to Existing Equipment*

The initial intent of the DDS system implementation will be to minimize the cost impact on the existing manual and automated systems. The initial level of functionality is expected to be implemented as a stand-alone system, as planned during the Pilot Production System. As work is diverted from existing systems to DDS, resources in support of existing systems can be reduced. As the DDS system is used increasingly to order, process, and reproduce documents at the STI Facility, there will be fewer resources required from existing systems that duplicate what DDS can now accomplish. This could amount to a reduction in mainframe space requirements and a reduction in processing time once all 16 sites are using the DDS remote access capabilities. This is due to a reduction in online ordering through NASA/RECON. These impacts have not been quantified due to their perceived minimal effect on current operations.

Additional reductions in the workload of the microfiche and xerographic reproduction equipment will occur as more work is diverted to the DDS system. As the Full-Scale System usage increases the proportion of digital reproduction activity, that portion of the current reproduction equipment that is used to service requests for NASA Technical Reports could be phased-out or not require further upgrading, resulting in additional savings in maintenance and/or upgrade costs. These potential savings have not been quantified because they will probably occur after the Full-Scale System life cycle.

It is assumed that the DDS Pilot Production System document file server will be upgraded from a 386-based PC operating at 25 MHz to a more powerful PC that is based on the Intel 80486 (i486) microprocessor operating at 33 MHz or faster. An additional 8 megabytes (MB) of memory will be installed in this file server at the beginning

of the Full-Scale System. This file server upgrade is planned to accommodate the extra processing load due to additional local and remote imaging workstations in the Full-Scale System, based upon the current assumed requirements.

6.1.1.2 *Additional Equipment to Pilot Production System*

The Pilot Production System was designed with an open architecture to facilitate the transition to Full-Scale System implementation. It is recommended that the following additional major components be added to the DDS base LAN system to handle the increased functionality and use of the Full-Scale System. These components include two document request processing workstations, one additional reproduction workstation, a LAN upgrade, and additional software.

1 – Two document request processing workstations at the STI Facility

These workstations are two PC 386 base units that provide the human interface to the centralized document request processing side of the DDS system. These workstations will be the control and initiation sites of reproduced NASA Technical Reports printed at the STI Facility. Supported functions include order validation, order processing and a remote troubleshooting facility for the document processing part of the DDS system. It will provide the management and statistical reporting function as well as those functions needed to integrate DDS to the other systems at the STI Facility for overall management of the STI Facility's mission. These workstations will contain fax send-and-receive capability and a laser printer for printing received fax documents and preparation of rush orders. It is possible to use the existing PC 386 base unit from the upgraded document file server, as assumed in section 6.1.1.1, *Impacts to Existing Equipment*, instead of purchasing one of these document request processing PC 386 base units.

2 – One additional reproduction workstation at the STI Facility

The initial reproduction workstation and printer configuration will be augmented with another PC 386 base unit and laser printer. This will provide redundancy to ensure continuation of operation in addition to serving as a convenient reproduction contingency capacity for peak printing periods.

3 – LAN upgrade at the STI Facility

The major constraint to remote interactive imaging applications is the prohibitive cost of high-bandwidth/high-transfer rate communications. Secondary to this restriction are the limitations of current LANs and their marginal transfer rates for imaging applications. The promise of high transfer rates—as fast as 100 Mbps using a

fiber distributed data interface (FDDI)—is currently available only on a limited scale and at a high cost. It is expected that by the time of the Full-Scale System procurement, the cost of this technology will be acceptable and the requisite software will be available. This upgrade is a key and essential feature to extend the core production DDS system to a STI Facility-wide work flow enterprise. Alternatively, the addition of a separate LAN (sub-LAN) and file server for the workstations located in the STI Facility's Document Request Services and Reproduction Services could provide the functional equivalent of FDDI bandwidth on a single LAN.

4 – Software

No component is more crucial to the overall success of the DDS system than the software that is needed to provide the integration of general-purpose devices to work efficiently for all the specialized tasks that comprise this system. Software will largely characterize the functionality of the DDS Full-Scale System, determining what the system will and will not be able to do. The prime productivity impediment of contemporary computer systems increasingly consists largely of quality software which requires much effort in analysis and design. Software makes an open architecture such a cost-effective objective. This is a major area where enhanced productivity will be realized by being designed and engineered from the start of the DDS project.

It is expected that the software developed and tested during the pilot for remote access can be used in the Full-Scale System. The major additional software needed for the Full-Scale System will be the requirement for multitasking remote access requests as well as monitoring and managing the DDS network.

Other software issues include inquiry programs for document processing workstations and a reporting and statistical monitoring will be needed to integrate DDS-provided services into the monthly Report on Facility Operations. The specific software to be provided will be based on the requirements and a detailed design activity to be performed in the future.

6.1.1.3 *Communications Requirements*

The key to effective use of future communications technology is to build a flexible platform that can progressively adapt to new modular components with better performance/price characteristics in the future. In recent years, the continental United States has practically been rewired with optical fiber, offering the possibility of networks and equipment to provide the kind of transfer ratios that will make imaging applications

more productive and practical. Costs of wide-band lines have plummeted, with new services almost continually being offered. In all likelihood, the communications-service type DDS will actually use five years from today has not even been conceived.

Nevertheless, it has been agreed upon and will be assumed that a minimum or the equivalent of a 56 Kbps communications line, provided by the NASA PSCN, will be available for use at the STI Facility and remote sites. This can be either a fast packet-switched or dial-up circuit-switched service to be determined by the PSCN network administrator. While it is likely that other communications services might eventually prove more viable and desirable, such as fractional T1 or Integrated Switched Digital Network (ISDN), the following device is still necessary regardless of the selected service.

1 – Communications server

This PC 386 base unit (25-MHz speed, 8MB of RAM, and 300MB hard-disk drive) will directly handle the electronic interface between the communications lines at 56 Kbps and the LAN access to the storages devices and file servers that contain the document pages to be transmitted. These functions are accomplished with interface adapters that will be matched to the communications services that are used and provided, such as a modem, CSU/DSU (channel service unit/digital service unit), or an ISDN adapter, among others, as required.

This workstation will provide the requisite buffering and request queue management to maximize throughput and minimize turnaround for remote communications traffic. At the same time, other existing processes on the system are to be monitored and should not adversely impact such operating processing tasks as scanning and indexing that are also contending for access to the LAN and its link to necessary local file transfer services. The DDS system's open architecture will be exploited to use its inherent flexibility for this Full-Scale System modification.

6.1.2 Remote Site

The DDS remote workstation as described in the Pilot Production Cost/Benefit Analysis is the same platform for Full-Scale Production. Refer to section 2.2.2.5 in the Cost/Benefit Analysis report for more details. More elaborate software is required to control the transmitted resolution level (75 to 300 dpi), provide for interactive browsing (view only or page print), process document print requests on-demand or in a batch/deferred mode, and process transmission request management features, such as deferred request status summary screen. An optional magneto-optical (M-O) disk drive would provide removable storage for a large number of users to advance order documents for viewing at a scheduled time (staging of image files).

Similarly to the configuration at the STI Facility, each site will have a matching data interface adapter, preferably a single PC add-in board, to receive images at 56 Kbps that the STI Facility will have transmitted. Software will also have to be included. At minimum, this will mean a network control program, a line control program, a workstation-to-communication-interface program, and an image-retrieval application program.

Ideally, a single board architecture will minimize hardware components and improve reliability and maintainability for performance considerations. It is recommended that a terminal emulation card and software also be included with each remote site unit for integration with the existing NASA/RECON application using existing circuits at the NASA Centers at no charge. This will allow the use of Dynamic Data Exchange (DDE) techniques or the equivalent with the STI Facility host mainframe computer. The main derived benefit of this configuration would be the capability to supply automatically NASA/RECON accession numbers to the DDS system without keying in the numbers.

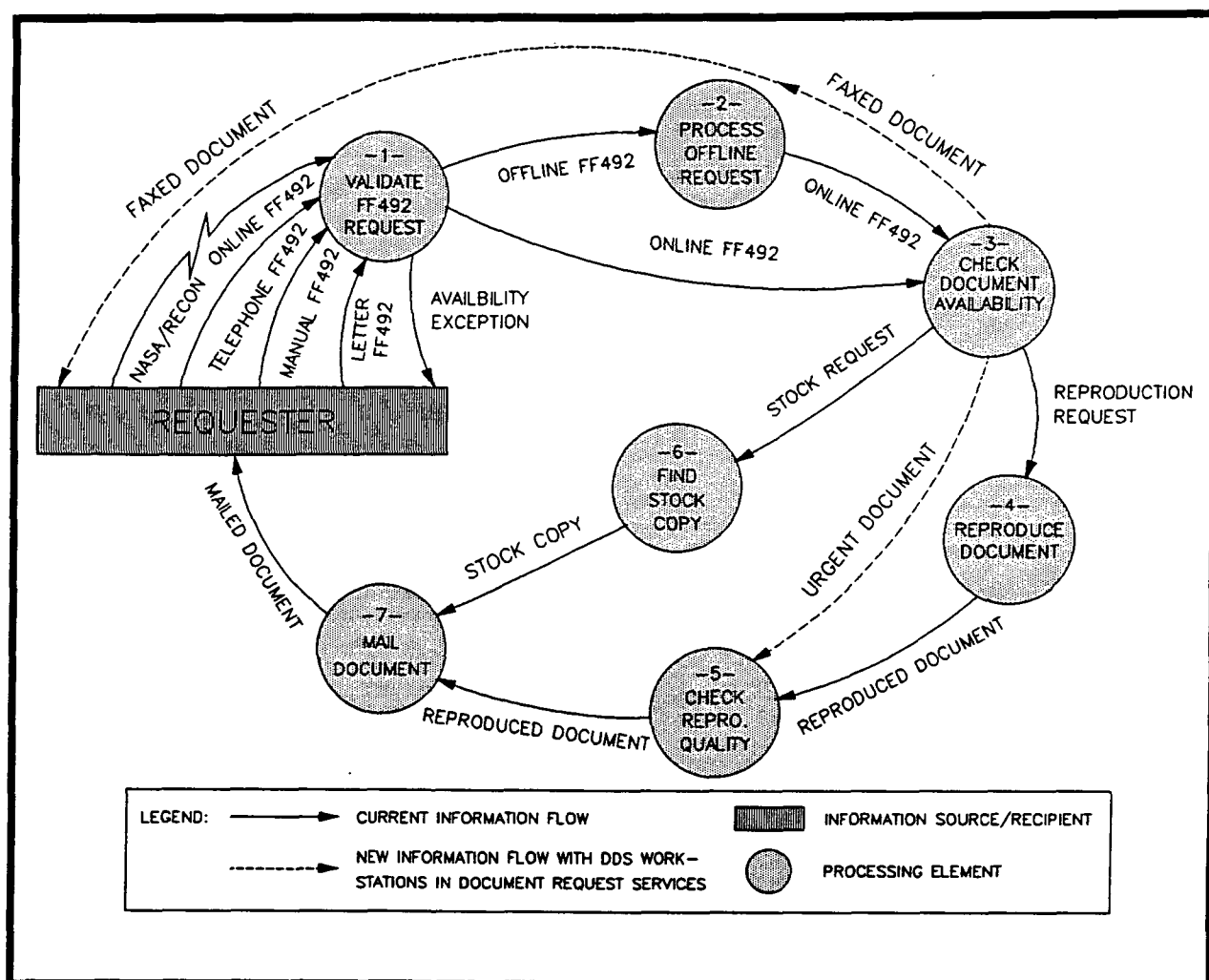
6.2 Personnel

New and revised manual procedures as a result of the DDS Full-Scale System are discussed in terms of impacts to personnel at the central and remote sites.

6.2.1 STI Facility

Refer to figure 6-1, the document request service system, for the information flow diagram depicting relevant functional elements.

Figure 6-1. Document request service system.



6.2.1.1 Document Request Services at the STI Facility

Process elements 1, 2, 3, and 5, shown in the figure in section 6.2.1, comprise the primary functions, including their associated information flows, for the STI Facility's Document Request Services. Even with the additional services provided to users as a result of new DDS capabilities, approximately 1,000 labor hours could be redirected from the existing Document Request Services function. Such a staff reduction could be accomplished if the DDS production system successfully improves productivity in centralized servicing of document requests and in diverting the volume of requests from centralized servicing to local, remote servicing. With productivity improvements in reproductions, quality assurance checking, and packaging, it is assumed that the number of labor hours required to service each request will be reduced. This will not necessarily lead to a staffing change, but could be manifested as improved efficiency. This redirection might not be feasible if the level of enhanced services and additional services increases greatly.

6.2.1.2 *Reproduction Services at the STI Facility*

Processing element 4, shown in the figure in section 6.2.1, encompasses the STI Facility's Reproduction Services and incorporates the manual labor-intensive microfiche retrieval and refiling tasks involved in current microfiche blowback document reproductions. During the Full-Scale System, a significant amount of document reproductions from blowback and xerographic reproduction equipment will be directed to DDS reproduction workstation laser printers. It is likely that support to the reproduction function could be reduced by as much as a 1,000 labor hours due to automation of the search, retrieval, and printing functions, and the elimination of refiling of microfiche materials. The actual diversion of the fulfillment document reproduction requests from the STI Facility to the remote locations has not been estimated since it necessitates a study currently proposed to be included in the recommended communications requirements analysis.

6.3 Services

A description of the current document acquisition process is found in section 4.1 and appendix B of the DDS Cost/Benefit Analysis report. The receipt of documents, input processing, microfiche production and initial distribution steps will not be significantly affected by either the Pilot Production or Full-Scale Systems. Archival microfiche storage will be augmented by the electronic media optical disk storage. The electronic storage document base gradually increases throughout the Full-Scale System, as depicted in the first table in section 3.1.4, *Document Acquisition*. Secondary distribution will be impacted by the Full-Scale System in the two operating units described in section 6.2, *Personnel*. The service-oriented impacts consist of enhancements to existing procedures in both operating units and additional services that can be provided by Document Request Services at the STI Facility.

Changes to the procedures in Document Request Services will be implemented in the following areas:

- a. The DDS system will provide improved and expedited validation of reproduced documents during quality control tasks by way of electronic access to document images. Pages that were not reproduced by the laser printer in Reproduction Services (such as omitted or misprinted pages) can be quickly reprinted by the Document Request Services workstation laser printers and reinserted into the reproduced document on demand. This capability will save much time and effort currently spent rerouting incorrectly reproduced documents to and from Reproduction Services.
- b. Additional user assistance will be available in the document identification process, both prior and subsequent to the issuance of a document request, because STI Facility staff will

have rapid access to electronic documents while a user is on the phone. Title and subject searches via the DDS electronic version of the document Table of Contents will facilitate access to specific text and graphic material that might be of interest to the user.

- c. Electronic image access will be provided for staff involved in content analysis and selection for the continuing bibliography generation tasks. Staff will be able to peruse items to determine whether or not they are pertinent to a particular bibliography, thereby creating a higher-quality publication.
- d. Express delivery could be expedited for rush document request orders using DDS workstations, laser printers, and overnight mail.
- e. Double-sided document reproduction and more manageable handling of peak document requests will be possible with the workstations to be located in the Reproduction Services.

Two services that are currently unavailable will be provided by the Document Request Services. These additional services are as follows:

- a. Printing of short documents, under 25 pages for example, can be accomplished more quickly and efficiently by Document Request Services, which could decrease the total turnaround time of the document request. See figure 6-2, the DDS document request service system, for the revised information flow diagram.
- b. Extensive use of fax services will be possible using the powerful fax capability within the DDS workstations, including resolutions as high as 300 dpi. Sending and receiving fax documents for document requests and urgent documents to be reproduced will be greatly simplified and manageable on a larger scale than is currently possible with existing personnel and equipment.

7-COST SUMMARY

In section 6-*FULL-SCALE SYSTEM IMPACTS*, impacts were characterized in terms of equipment, personnel, and services. In this section, the impacts of the Full-Scale System are viewed in terms of cost in a variety of areas. System maintenance costs are discussed for both the Pilot Production and Full-Scale Systems.

7.1 Description of Costs

Estimated costs for the Full-Scale System are considered in terms of equipment and labor required in addition to those cost items provided for in the Pilot Production System at the STI Facility, referred to as the central site. No recurring costs have been identified for the Full-Scale System beyond those required to operate and maintain the Pilot Production System which are excluded from this treatment. Costs at both the central site and the 16 selected NASA Centers, referred to as remote sites, are considered. Full-Scale System costs are categorized as follows:

- Capital equipment costs at the central and remote sites
- Nonrecurring labor costs at the central and remote sites

System maintenance costs for both the Pilot Production and Full-Scale Systems are considered at the end of this cost summary section.

7.2 Equipment Costs

Equipment costs are presented by central- and remote-site configurations.

7.2.1 Central Site

As stated in section 6.1, *Equipment*, the Full-Scale System requires upgrades to existing equipment in the Pilot Production System and completely new equipment to support the 16 remote sites with on-demand, electronic access to NASA Technical Reports. The upgrades consist of increased performance to the Document File Server and larger capacity/higher bandwidth for the LAN at the STI Facility. Additional equipment at the central site consists of:

- One communications server and software
- One additional reproduction workstation
- Two document request processing workstations

Refer to section 6.1.1.2, *Additional Equipment to Pilot Production System*, for an explanation of the different components on the above new equipment. In formulating these costs, it was assumed that all capital equipment to be located at the central site would be purchased at current prices under contract NASW-4069F, the STI Facility capitalized equipment pro-

curement vehicle. Furthermore, it was assumed that labor in support of the DDS implementation would be applied to NASW-4070, the labor, service, and maintenance contract in place at the STI Facility.

7.2.2 Remote Sites

Equipment to be installed at the remote sites consists of a complete image retrieval and reproduction workstation with the communications interface provided. Communications circuits from the remote workstation to the STI Facility is assumed to be provided by PSCN at no charge to NASA Headquarters Code NTT. Refer to table 7-1, the summary of estimated cost elements (in dollars), for the estimated cost figures for the upgrades and new equipment required at both the central and remote sites.

Table 7-1. Summary of estimated cost elements (in dollars).

CAPITAL EQUIPMENT ELEMENTS		COSTS
Central site:		
Document file server upgrade		3,500
LAN upgrade		2,000
Communications server		11,500
Reproduction workstation		13,500
Two document request processing workstations, at \$13,250 per workstation		26,500
Sales tax (5 percent) and material handling fee (2 percent)		3,990
SUBTOTAL of central site capital equipment costs		\$ 60,990
All 16 remote sites:		
15 remote image workstations at \$17,000 per site ^a		255,000
SUBTOTAL of remote site capital equipment costs		\$255,000
TOTAL capital equipment costs for central and remote sites		\$315,990
NONRECURRING LABOR ELEMENTS ^b		COSTS
Central site:		
System installation		5,000
System integration		38,000
Training session		3,000
SUBTOTAL of central site nonrecurring labor costs		\$ 46,000
All 16 remote sites:		
15 system installations at \$2,000 per site ^a		30,000
16 training sessions at \$3,000 per site		48,000
SUBTOTAL of remote site nonrecurring costs		\$ 78,000
Central project management and administrative support		12,400
SUBTOTAL of central general administration costs		\$ 12,400
TOTAL nonrecurring labor costs for central and remote sites		\$136,400
GRAND TOTAL capital equipment & nonrecurring labor costs for central & remote sites		\$452,390
^a It is assumed that the remote workstation installed at Code NTT during the Pilot Production System will remain and can be adapted for use in the Full-Scale System.		
^b All labor costs are estimated at \$35 per hour, fully burdened, for an eight-hour day.		

7.3 Labor Costs

Labor costs are discussed for both the central- and remote-site requirements.

7.3.1 Central Site

There is a one-time requirement for the expenditure of labor in the central site to install and test the upgrades and new equipment described in section 7.2.1, *Central Site*. Additional software development and enhancements are necessary to meet the functional requirements of the remote access applications. Thorough system testing of central and remote site applications is critical to the success of the Full-Scale System. Software development, testing and other system enhancements are referred to as systems integration. Also, training must be provided to the new users at the central site and to DDS operational personnel. Training costs represent only the cost of providing the training by central site personnel; it excludes the cost of labor for NASA staff to receive this training.

7.3.2 Remote Sites

There exists an installation requirement at each remote site for the imaging workstation configuration. This should be accomplished within two working days. A modest travel budget was included in the installation cost item. Additionally, user training must be provided for library personnel at each remote site. This could be scheduled during a two-week period in which rotation classes and workshops would be available for both library staff and interested researchers. Travel and overnight accommodations were considered in the training cost item. The table in section 7.2.2 also lists the primary labor cost estimates dealt with in this Impact Analysis.

7.4 Summary of Cost Categories

In addition, the table in section 7.2.2 gives the total cost for capital equipment at the central site as \$60,990 and at the remote sites as \$255,000. This results in a total for all capital equipment of \$315,990. Total labor costs for the central site is \$46,000 and at the remote sites, \$78,000. A 10-percent factor for project management and administrative support was multiplied against the total nonrecurring labor costs to produce the central general administration cost total, estimated at \$136,400. The total Full-Scale System add-on cost to the Pilot Production System is \$452,390, exclusive of both recurring and nonrecurring costs for communications services.

Another way to view the Full-Scale System costs is from the viewpoint of total costs to the central site exclusively versus the total costs to a single remote site. This approach facilitates the budgeting process by providing NASA Headquarters Code NTT with a cost breakdown for the Code NTT financial responsibility (central site cost items) separated from the remote site cost components. Also, the level of funding required by each remote site can be assessed for feasibility considerations and planning purposes. The total labor and equipment cost for the central

site is assumed to be \$107,600. The total cost for a single remote site is \$22,500. The total cost for all remote sites is \$340,800. Table 7-2, the summary of estimated costs by sites (in dollars), provides the supporting information for this alternative costing viewpoint.

Table 7-2. Summary of estimated costs (in dollars) by site.

CENTRAL SITE		
Capital equipment elements		60,990
Nonrecurring labor elements ^a		46,000
Project management and administrative support		4,600
SUBTOTAL of central site costs		\$111,590
REMOTE SITES		
Single remote site:		
Capital equipment elements	17,000	
Nonrecurring labor elements ^a	5,000	
Project management and administrative support	500	
Single remote site costs	\$22,500	
All 16 remote sites:		
15 remote image workstations at \$17,000 per site ^b		255,000
15 system installations at \$2,000 per site ^b		30,000
16 training sessions at \$3,000 per site		48,000
Project management and administrative support		7,800
SUBTOTAL of remote sites		\$340,800
TOTAL COSTS		\$452,390
^a All labor costs are estimated at \$35 per hour, fully burdened, for an eight-hour day.		
^b It is assumed that the remote workstation installed at Code NTT during the Pilot Production System will remain and can be adapted for use in the Full-Scale System.		

7.5 System Maintenance Costs

System maintenance costs are calculated, based on the capital equipment purchases, excluding consumable items, such as storage media and computer supplies. It is assumed that all capital equipment purchased will include a 12-month warranty. An average of 15 percent has been assumed for all equipment maintenance fees. Pilot Production System maintenance years are years two through ten while Full-Scale System maintenance is required in Pilot Production years seven through ten or Full-Scale years two through five. An additional 8 percent has been

used as a planning factor to cover expenses for consumables, materials, and supplies. Refer to table 7-3, the summary of maintenance costs at the central and remote sites for the Pilot Production and Full-Scale Systems over a 10-year life cycle, for total maintenance and system procurement costs at the STI Facility and the 16 NASA Centers, based on the above assumptions.

TABLE 7-3. *Summary of estimated maintenance costs at the central and remote sites for the Pilot Production and Full-Scale Systems over a 10-year life cycle.*

PILOT PROD. YEAR	FULL- SCALE YEAR	PILOT PRODUCTION SYSTEM COSTS			FULL-SCALE SYSTEM COSTS		
		EQUIP.	MAINT.	TOTAL	EQUIP.	MAINT.	TOTAL
One		194,798		194,798			
Two			44,803	239,601			
Three			44,803	284,404			
Four			44,803	329,207			
Five			44,803	374,010			
Six	One		44,803	418,813	315,990		315,990
Seven	Two		44,803	463,616		72,678	388,668
Eight	Three		44,803	508,419		72,678	461,346
Nine	Four		44,803	553,222		72,678	534,024
Ten	Five		44,803	598,025		72,678	606,702
System maintenance costs			403,227			290,712	
System maintenance costs for Full-Scale System years one through five			224,015			290,712	
TOTAL Systems maintenance costs Pilot Production and Full-Scale Systems maintenance costs at the central and remote sites for the five-year period of the Full-Scale System							514,727

The total maintenance costs at the central sites and all remote sites for the Pilot Production and Full-Scale Systems are \$403,227 and \$290,712, respectively. The five-year portion of the Pilot Production System maintenance plus the Full-Scale System maintenance cost at the central and remote sites is \$514,727.

Table 7-4, the summary of maintenance costs only at the central site for the Pilot Production and Full-Scale Systems over a 10-year life cycle, gives the total maintenance and system procurement costs at the STI Facility only, based on the above assumptions.

TABLE 7-4. Summary of estimated maintenance costs only at the central site for the Pilot Production and Full-Scale Systems over a 10-year life cycle.

PILOT PROD. YEAR	FULL- SCALE YEAR	PILOT PRODUCTION SYSTEM COSTS			FULL-SCALE SYSTEM COSTS		
		EQUIP.	MAINT.	TOTAL	EQUIP.	MAINT.	TOTAL
One		175,957		175,957			
Two			40,470	216,427			
Three			40,470	256,897			
Four			40,470	297,367			
Five			40,470	337,837			
Six	One		40,470	378,307	60,990		60,990
Seven	Two		40,470	418,777		14,027	75,017
Eight	Three		40,470	459,247		14,027	89,044
Nine	Four		40,470	499,717		14,027	103,071
Ten	Five		40,470	540,187		14,027	117,098
System maintenance costs			364,230			56,108	
System maintenance costs for Full-Scale System years one through five			202,350			56,108	
TOTAL Pilot Production and Full-Scale Systems maintenance costs only at the central site for the five-year period of the Full-Scale System							258,458

The total maintenance costs only at the central site for the Pilot Production and Full-Scale Systems are \$364,230 and \$56,108, respectively. The five-year portion of the Pilot Production System maintenance plus the Full-Scale System maintenance cost only at the central site is \$258,458.

7.6 Estimated Total Implementation and Maintenance Costs Under STI Facility Contracts

In presenting this total cost summary for the DDS Full-Scale System implementation under the NASA STI Facility contracts, no cost for recurring communications service or nonrecurring capital equipment for the 16 remote sites have been included in this cost summary. It has been assumed that 56 Kbps point-to-point communications service will be provided by NASA's PSCN, with no cost charge-back to the STI Facility or Code NTT. Also, it has been assumed that all remote access equipment to be located at NASA Centers will not be purchased under the STI Facility contracts. It has been assumed that STI Facility labor will be used to support installation and training at the remote sites.

The cost of the total capitalized equipment at the central site is estimated to be \$60,990 and is to be applied to contract NASW-4069F. The total implementation labor and maintenance cost is estimated to be \$394,858 and is to be applied to contract NASW-4070. This cost estimate is composed of \$258,458 in central-site maintenance fees and \$136,400 in implementation labor costs. These costs do not reflect the recurring operational labor at the STI Facility. All of the above costs are stated in terms of current prices.

8-ANALYSIS OF FINDINGS

Major findings resulting from this Impact Analysis are presented in this section. A corresponding conclusion is drawn for each finding, based on the analysis performed by the DDS staff.

FINDINGS
<ol style="list-style-type: none">1. Feasibility of Full-Scale Implementation2. Potential Queuing Problem with Communications Traffic3. Variability in Actual Cost of Remote Access Capability4. Ongoing Need to Reassess Remote Access Methods

8.1 Feasibility of Full-Scale Implementation

Based on the current set of assumptions described in the Cost/Benefit Analysis report and in this Impact Analysis, it appears that remote access is feasible to the centralized DDS system from the 16 NASA Centers using existing technology and customized remote access applications software. Future developments discussed by the communications vendors in trade journals and at communications conferences portray a very powerful set of communications services (for example, fractional T1 through T3), increasingly inexpensive communications devices including single board PC level direct connections to these powerful services, and commercially available software to support a wide variety of remote access to large files such as proposed DDS image traffic. Ongoing technology assessment and analysis in light of DDS requirements is essential to providing cost effective remote access solutions within the DDS project framework. Multiple phases of the proposed communications requirements analysis, recommended in the Cost/Benefit Analysis report, should be planned and executed throughout the life cycle of DDS to ensure the appropriate technology injection of critical remote access communications elements to meet adequately the assumed and evolving requirements by the STI Facility users.

Additional analysis, which is not included in this report, is required to assess potential impacts to other STI Facility operational staff, such as Input Processing, in order to make full use of the significant functionality provided by the Full-Scale System. As discussed in Finding 2 of the Cost/Benefit Analysis report, the many layers of multiple assumptions used during all analysis to-date presents risks that could be minimized by further requirements analysis and ongoing cost/benefit justifications. Additionally, impacts based upon the current gross, high-level system design are somewhat tenuous and under no circumstances provide the basis for a satisfactory DDS procurement.

8.2 Potential Queuing Problem with Communications Traffic

As discussed in Section 4, Description of Model, a critical element in any multiple channel service-based system, such as the Full-Scale System, is the modeling of number of requests per time period and amount of time required to service a request in a probabilistic fashion using well-established queuing theory techniques. Expected wait times from this model are directly related to effective response times that the end user will experience. The relationship between server use, how busy the system actually is, and the queue wait time (delay) with respect to the server queue length is not linear. When reaching a certain level in using the service, rapid deterioration of service will occur, resulting in unacceptable delays if the system is improperly sized. Only simulation techniques can adequately determine this sizing requirement. Problems with both local and remote communications transfers of large image files in a random manner within DDS is a serious topic for additional analysis recommended in the proposed communications requirements analysis effort.

8.3 Variability in Actual Cost of Remote Access Capability

There is a relatively low confidence level in the cost assumptions in delivering Full-Scale System remote access to all 16 remote sites at an acceptable level of service (such as on-demand printing of high-quality, complete documents or interactive browsing of single pages at a time within variable resolution scales). A network design effort with the full cooperation of authorized NASA representatives, such as the PSCN technical contractors, is vital to a cost effective solution to the remote access requirements within the Full-Scale System. Other NASA image transmission and document storage projects should be explored and evaluated in terms of techniques and lessons learned to avoid subtle errors and biases in technical approaches and to minimize the redundancy of analysis and design efforts. Input from other NASA and federal government technical expertise could increase the confidence level of further analysis in the future. Still there is a chance that the preliminary applications review performed by the STI Facility staff is accurate in assessing the dearth of interactive, remote access of high quality document images such as required by the assumed DDS functional requirements.

As a result of this confidence level, no response time ranges have been specified within this Impact Analysis. This important, user-oriented metric requires much analysis of current usage patterns in light of possible increased NASA/RECON II usage and could be modeled in the proposed simulation activity during the communications requirements analysis. The ultimate cost justification to NASA Center remote site users might be dealt with differently at each Center although the net cost to the NASA Center for DDS remote access and the operational impact of additional library services at the NASA Centers should be of major concern. The DDS Full-Scale System is envisioned to provide a platform for adding new functionality (such

as full-text search of ASCII text within documents), different document types, and additional NASA/RECON users in the future. These future plans should be evaluated in light of service value to the users versus end user cost justification procedures.

8.4 Ongoing Need to Reassess Remote Access Methods

It is clear from this Impact Analysis that the sensitivity in cost and functionality of various remote access methods is of utmost importance to the success of DDS beyond the initial STI Facility use. The customized applications software to perform the remote access function is comprised of many elements. In order to achieve economies during software development and maintenance activities, it is intended that the image retrieval software module be standard throughout DDS applications, both at the STI Facility and the remote sites. This specific software component could be quite complex, yet its criticality can not be stressed too much. Diligent technical efforts must be expended to stay abreast of current and emerging technologies in areas such as personal computing, communications services, NASA-provided administrative communications support (such as PSCN), image processing and transmission techniques used throughout NASA, and digital storage devices. The possibility of distributing the DDS image database on high-capacity, inexpensive optical media in the future could greatly reduce the overall need for remote transmission of NASA Technical Reports during the Full-Scale System life cycle.

9-RECOMMENDATIONS

In this section, recommendations are specified that form a plan of action for NASA to proceed with the implementation of DDS in a cost-effective and technically viable manner.

RECOMMENDATIONS

1. Proceed with the DDS Project
2. Proceed with Communications Requirements Analysis
3. Revise Constraints about Pilot Production System
4. Full-Scale System Implementation Future Phases
5. DDS Development Methodology and Project Plan

9.1 Proceed with the DDS Project

As stated in section 8-*ANALYSIS OF FINDINGS*, remote access is feasible, probably desirable, and can be provided at the 16 NASA Center remote sites with existing technology. The remote access system components will probably become less costly by the time of Full-Scale System procurement. A phased, communications requirements analysis is recommended to be conducted throughout the life cycle of DDS to ensure the appropriate technology injection of critical remote access communications elements to meet adequately the assumed and evolving requirements by the DDS users. With sufficient allocation of labor resources, a rapid prototyping development methodology could be used to demonstrate feasibility of both the basic DDS concept and Full-Scale System remote access with the procurement of the DDS Prototype System as specified in the DDS Prototype System Acquisition Plan. Yet, significant systematic analysis and detailed design is needed before proceeding with the Pilot Production and Full-Scale Systems.

9.2 Proceed with Communications Requirements Analysis

It is further evident from this Impact Analysis that the recommended communications requirements analysis effort should be well designed and the first phase initiated as soon as possible. Proposed activities, in addition to those discussed in the Cost/Benefit Analysis report, are as follows:

1. Solicit remote access user input
2. Document remote access user requirements
3. Prepare remote access retrieval mockup software
4. Assess document image compression and file-transfer factors
5. Analyze NASA/RECON online order command traffic patterns
6. Conduct a detailed remote communications technology survey

7. Develop DDS computer simulation for local and remote traffic
8. Design more detailed DDS network alternatives
9. Estimate costs for DDS communication alternatives
- 10 Evaluate alternative DDS networks

It is the opinion of the DDS staff that the remote communications requirement dictates further simulation and analysis in order to achieve a minimal confidence level for implementation of remote access functionality.

9.3 Revise Constraints about Pilot Production System

Having performed this Impact Analysis and discovering additional technical and administrative information, it is obvious that some of the assumptions and constraints regarding implementation of the Pilot Production System might be unnecessary and counterproductive. The selection of NASA Headquarters Code NTT as the only site with which to test the remote access capability during the Pilot Production System is possibly unwise. It is highly recommended to use a more typical user site as a pilot site, such as GSFC, LaRC, or both, since these sites are large users of NASA/RECON and are therefore more likely to test the remote access capability relative to typical end-user operation and be able to provide meaningful feedback for the Full-Scale System implementation. Some limited use of 56 Kbps communications lines should be evaluated with some of the proposed variable resolution techniques using actual NASA Technical Report page images to estimate ranges of anticipated effective response times from the end user perspective.

In addition, to test the remote access capability properly during the Pilot Production System time frame, it might be useful to prototype that capability during the DDS Prototype System evaluation period. Alternatively, a separate DDS remote access prototype procurement or evaluation period might be in order. Finally, both the Pilot Production and Full-Scale Systems should be reevaluated in terms of duration and objectives. This would most effectively be accomplished after the initial remote access study is completed. At least the Pilot Production System should be shortened to two years to provide some remote access from NASA Centers at an earlier date than originally planned (five years after the Prototype System is installed).

As has been previously stated in section 8.4, *Ongoing Need to Reassess Remote Access Methods*, the cooperation of PSCN technical representatives and other NASA image and document storage project technical staff is vital to determining the most cost-effective solution to the remote access requirements within the Full-Scale System. Use of NASA technical forums and user groups in addition to tying into other NASA federal government technical expertise and relevant special interest groups could be of great benefit to DDS in the future.

9.4 Full-Scale System Implementation Future Phases

A phased implementation within the Full-Scale System framework is recommended in two dimensions, the connection of remote access users and in terms of functionality. First, the initial 16 NASA Centers should be phased in during an initial time frame. For example, two large users and two smaller users could be added to the DDS network incrementally, over three months. This approach would require one year to implement for all 16 remote sites. Also, future functional enhancements could be phased in, after all remote sites are operational and stable.

Functional enhancements that could be considered should include the following:

- * Full-text search
- * Electronic document acquisition
- * CD-ROM distribution
- * Alternative media conversion

9.5 DDS Development Methodology and Project Plan

This Impact Analysis addresses the key issues of feasibility and planning for the two central objectives of the DDS project: to scan, digitize, and store NASA Technical Reports at the STI Facility for archival blowback purposes; and to provide remote electronic retrieval of report images. Nevertheless, this Impact Analysis report raises as many important issues as it resolves. These issues can be resolved with a more deliberate development methodology.

The subjects and components involved in implementing the Full-Scale System are sufficiently complex and unresolved to necessitate the execution of a requirements, planning, and design stage. No amount of structured analysis extrapolation on assumptions can be substituted for the required positive knowledge to insure project success. It is particularly true in the remote retrieval system that users' input be solicited so that the delivered product meets their needs with a sufficiently acceptable look, feel, and performance. This simple but crucial step will allow both major and minor details to be adjusted as necessary beforehand. This no-surprises design methodology is strongly advocated.

The design methodology should include strategic planning analysis from the beginning. The initial stand-alone feature of DDS is not a desired goal in itself. The degree to which the operations and structure at the STI Facility are reengineered to integrate the DDS system will determine additional benefits of this innovative system.

The basic minimum required life cycle phases for the implementation of the DDS system remain unchanged, even with a rapid development plan. One starts with requirements and planning and advances to design, preferably strengthened with a prototype. These phases are

followed with an acquisition or procurement phase based on the functional and performance specifications of the previous phases. The last step is the switch-over phase, which includes testing, training, organizational changes, tandem operations, and audits.

10-APPENDIXES

The five appendixes in this section, which are identified in the box below, provide supplemental material to aid in further understanding of the body of the work presented in this Impact Analysis.

APPENDIXES
A-Assumed Full-Scale System Configuration
B-Comparison of Pilot Production and Full-Scale Systems
C-Future Capabilities
D-References
E-Glossary of Terms

A-Assumed Full-Scale System Configuration

Subsystem/Component

A. IMAGE CAPTURE SUBSYSTEM

1. PC base unit
2. Landscape imaging monitor
3. Scanner with document feeder
4. Image-processing board
5. Optical character recognition board
6. Image display interface board
7. Scanner interface board
8. Serial hand-held scanner
9. Serial trackball
10. Power organizer
11. Computer desk and table
12. Scanner table
13. Text-capture software
14. SCSI adapter board

B. QUALITY CONTROL SUBSYSTEM

1. PC 386/25 base unit
2. Gray-scale imaging display
3. Optical character recognition board
4. Image display board
5. Image printer board
6. Image printer video board
7. Image-enhancement board
8. High-resolution scanner
9. 5.25-inch rewritable optical disk
10. Low-speed laser printer
11. Serial trackball
12. Power organizer
13. Computer desk and table
14. Printer and scanner table
15. SCSI adapter board
16. Image-capture software
17. Image-enhancement software

C. DOCUMENT FILE SERVER

1. PC i486/25 base unit
2. Portrait imaging display
3. 12-inch WORM with controller
4. 12-inch WORM
5. 12-inch WORM jukebox
6. 5.25-inch rewritable optical disk
7. Display board
8. Display monitor
9. 3270 emulation board
10. 3270 emulation software
11. Remote-access image software
12. 9,600-bps modem
13. Power organizer
14. Computer desk and table
15. Laser printer table
16. External tape backup
17. SCSI adapter board
18. CD-ROM drive
19. Image file-server software
20. Data analysis software
21. Software integration tools

D. TWO REPRODUCTION WORKSTATIONS

1. PC base unit
2. Portrait imaging display
3. Image display board
4. Image printer board
5. Laser printer
6. Image printer video cable
7. Power organizer
8. Computer desk and table
9. Laser printer table
10. LAN printer control software
11. Serial trackball

**E. TWO DOCUMENT REQUEST
PROCESSING WORKSTATIONS**

1. PC base unit
2. Portrait imaging display
3. Image display board
4. Image printer board
5. Laser printer
6. Image printer video cable
7. Power organizer
8. Computer desk and table
9. Laser printer table
10. LAN printer control software
11. Serial trackball
12. 9,600-bps PC fax board

F. COMMUNICATIONS SERVER

1. PC 386/25 base unit
2. VGA color display
3. 3270 emulation board
4. 3270 emulation software
5. 56 Kbps interface adapter

6. Remote image software
7. Power organizer
8. Computer desk and table

G. LOCAL AREA NETWORK

1. LAN boards for eight workstations
2. LAN software

**H. 16 REMOTE-ACCESS
WORKSTATIONS**

1. PC 386/25 base unit
2. Portrait imaging display
3. 12-inch WORM with controller
4. 12-inch WORM disk
5. 5.25-inch rewritable optical disk
6. Image display board
7. Serial trackball
8. Laser printer
9. 9,600-bps modem
10. Power organizer
11. Computer desk and table
12. Laser printer table

B-Comparison of Pilot Production and Full-Scale Systems

This section presents a brief synopsis of important comparisons and contrasts between the Pilot Production and Full-Scale Systems.

B.1 Similarities between Pilot Production and Full-Scale Systems

The Pilot Production System and the Full-Scale System are complementary and necessary stages in the overall implementation of the DDS system. These serially implemented system levels provide the strategic plan to provide the functional goals of fast, efficient, and high-quality dissemination of NASA scientific and technical information.

The entire effort of the Pilot Production System produces the foundation that the Full-Scale System will be built upon. Software and hardware purchased for the Pilot Production System will also be used in the Full-Scale System. The Full-Scale System will add to the functionality of the Pilot Production as well as ensure the services piloted in the previous System reach the appropriate NASA audiences for the intended use.

The primary production capability of the Pilot Production System is the requirement to scan, digitize, and store the approximately 5,000 NASA Technical Reports annually at the STI Facility as electronic digital image files. This requirement continues for the Full-Scale System.

The secondary production capability of the Pilot Production System is the requirement to reproduce copies in paper media from any of the approximately 5,000 NASA Technical Reports annually archived at the STI Facility as image files. This requirement also continues for the Full-Scale System.

The tertiary capability of the Pilot Production System is the requirement to provide remote, on-demand electronic retrieval at NASA Headquarters Code NTT of DDS image files. This requirement also continues for the Full-Scale System.

B.2 Differences between Pilot Production and Full-Scale Systems

With one important distinction, the capabilities of the Full-Scale System are a difference only in quantity and not kind. While it is expected that the number of NASA Technical Reports produced will remain nearly constant, the archived database will be growing by 5,000 documents per annum. Therefore, the output workload of the DDS system will grow as the database does until about the tenth year of the project. A tapering-off effect of document reproduction produced outside of DDS is assumed to occur because the oldest reports diminish in interest level to researchers at about the same rate as new ones are added.

The secondary production capability of the Pilot Production will require an adjustment in the Full-Scale System, assuming that the first year of the Full-Scale System is during the sixth year of scanning. An additional laser printer will likely be needed to service reproduction requests. This printer is necessary to provide the reserve capacity to handle anticipated workload peaks because of the ever-increasing digital image database. In addition, DDS staff recommends that two document request processing workstations be added to maintain the production work flow and associated NASA procedures with reproducing NASA Technical Reports.

A subtle, yet important, distinction exists between the Pilot Production and Full-Scale Systems. Administrative control of document reproduction processing is expected to move from a currently mainframe-based system to a PC-based DDS system for both status checking and job scheduling. It is recommended to do these tasks in DDS after a foundation has been established in the Full-Scale System.

The central task of the Full-Scale System is the completion of the tertiary production capability of the Pilot Production System. On-demand, remote electronic retrieval of documents will be possible at the 16 major NASA Centers in a production capability as was piloted for NASA Headquarters Code NTT in the Pilot Production System. This expansion to additional NASA Centers will require a communications server workstation and some equipment upgrades to the base system at the STI Facility. Each NASA Center that participates in this remote image retrieval will need an image retrieval workstation as described in section 6.1.2, *Remote Site*.

C-Future Capabilities

Several enhanced functions and implementation approaches are possible that could significantly increase the use and benefits of the DDS Full-Scale System. The following items represent a tentative list of such enhancements:

1. Capture, storage, reproduction, and transmission of color document pages and materials
2. Expansion of document population beyond NASA Technical Reports to included source data files from cited research
3. Expansion of remote user population beyond the single workstation at each NASA Center; could distribute DDS database on the LAN(s) at each remote site or make DDS dial-up service available to any NASA/RECON user with a PC/AT and VGA graphics display (using the view page transmission technique referred to in section 4.2.1.2, *Annual DDS Traffic Projections*)
4. Integration of DDS with the NASA/RECON STIMS database
5. Backfile conversion of older documents
6. Secure transmission of limited distribution documents (that is, LSTAR 1X series reports) to remote sites via current automated request validation procedures; classified documents to be excluded

D-References

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E-Glossary of Terms

1:1 reproduction: This is an exact-size reproduction of an original document; for example, an 8.5-by-11-inch copy made from an 8.5-by-11-inch original document.

20:1 and 24:1 reproduction: These terms represent the amount of magnification (20 and 24 times, respectively) that is necessary to produce an 8.5-by-11-inch paper copy of an image stored on microfiche.

286: Intel's 80286 CPU, first present in the IBM PC/AT, is a 16-bit microprocessor capable of addressing larger amounts of memory than Intel's 8088/8086 microprocessors by using a protected mode.

386: Intel's 80386 CPU is its successor to the 286. Running at twice (or more) the speed of a 286, this 32-bit microprocessor adds additional memory management capability and can concurrently run multiple virtual 8086 windows.

Access time: The time required to gain entry to a specific location on a memory device.

Accession: This term indicates a surrogate record that identifies a document or a part of a document (analytic).

Address: The physical or logical location in a computer's memory of a quantity of data.

ADP: Automated data processing.

AGA: Advanced Graphic Applications Inc.

AIIM: Association for Information and Image Management.

AIM: NASA's Automated Information Management.

Analytic: This term refers to the logical concept of dividing a document, such as conference proceedings, into parts. Each part is known as an analytic, which is assigned an accession number. When a document is divided into analytics, the document and its analytics form a parent/child or primary/subsidiary relationship.

ANSI: American National Standards Institute.

Archival: This term, when used for media, means that it is readable (and sometimes writable) for a long time; "long" means anywhere from 5 to 100 years or more depending on who is speaking.

ASCII: American Standard Code for Information Interchange.

Aspect ratio: The relationship between the length and width of a two-dimensional area.

Asynchronous transmission: Transmission in which time intervals between transmitted characters might be of unequal length. Transmission is controlled by start and stop bits at the beginning and end of each character.

AT: Advanced Technology. IBM's 286-based PC/AT was its mid-80s successor to the IBM PC and PC/XT.

AT bus: The standard 16-bit device data path; first incorporated in the IBM PC/AT.

ATL: Automated Tape Library.

Attenuation: The decrease in magnitude of a signal.

b: Abbreviation for "bit."

B: Abbreviation for "byte."

B channel: Bearer channel. A channel that carries either voice or data at 64 Kbps in either direction and is circuit-switched.

Back-up: A copy of stored data.

Band splitter: A multiplexor designed to split the available bandwidth into independent narrower band subchannels, each suitable for data transmission at a fraction of the total channel's data rate.

Bandwidth: The range of frequencies that can be passed through a channel.

Baud: Unit of signaling speed. The speed in baud is the number of discrete conditions or events per second. If each event represents only one bit condition, baud rate equals bps. When each event represents more than one bit (for example, dibit), baud rate does not equal bps.

Baudot: Data transmission code in which five bits represent one character. Use of letters/figures shift enables 64 alphanumeric characters to be represented. Baudot is used in many teleprinter systems with one start bit and 1.42 stop bits added.

Bell 212: An AT&T-compatible modem that provides full-duplex (asynchronous or synchronous) 1,200-bps data transmission for use on the public telephone network.

BER: Bit error rate.

Bit: Short for "binary digit," a bit is a unit of computer information that can be represented by an electrical impulse, a magnetized spot, or a hole whose presence or absence indicates data.

Block: An amount of data move or addressed as a single unit.

Blowback: In micrographics, when a reduced image is projected back to its original size.

bpi: Bits per inch.

BRI: Basic Rate Interface; the ISDN standard governing how a customer's desktop terminals and telephone can connect to the ISDN switch. The BRI standard specifies two B channels that allow 64-kilobit-per-second simultaneous voice and data service, and one D channel that carries call information and customer data at 16 Kbps per second.

Broadband: A device that can accept a wide range of frequencies. Same as "wide band"; see "bandwidth."

BSC: Bisynchronous transmission. A byte- or character-oriented IBM communications protocol that has become the industry standard. It uses a defined set of control characters for synchronized transmission of binary-coded data between stations in a data communications system.

Buffer: (noun) A relatively small portion of memory in which data is kept briefly between or during steps of processing of that data. (verb) The use of a buffer to store data.

Bus: A data path shared by many devices (for example, multipoint line) with one or more conductors for transmitting signals, data or power. In LAN technology, a bus is a type of linear network topology.

Byte: A group of adjacent bits, often shorter than a word, that a computer processes as a unit, for example, an 8-bit byte.

Cache: Generally, temporary storage for data to which access must be very quick.

CALS: Computer-aided Logistics Support. A U.S. Department of Defense (DOD) initiative to provide a standardized method of exchanging text and images among multiple computer hardware and software platforms. CALS is actually a superset of existing standards governing formats for computer graphics files, document typesetting tags, and storing scanned images. See "CGM," "SGML," and "TIFF."

CAR: Computer-assisted retrieval.

Cartridge: In optical technology, an enclosure, generally of plastic in which an optical medium is kept for protection, also called a cassette.

CAV: Constant angular velocity. Describes a disk that always spins at the same rotation rate.

CCD: Charge coupled device.

CCITT: The International Telegraph and Telephone Consultative Committee.

CCS 7: A network signaling standard for ISDN that incorporates information from databases in order to offer advanced network services.

CD-ROM: Compact Disc-read-only memory. A version of the audio Compact Disc intended to store general-purpose memory.

CD: Compact Disc, the trademarked name for the laser-read digital audio disk, 12 centimeters in diameter, developed jointly by Philips and Sony; see "CD-ROM."

Central office: The building in which common carriers terminate customer circuits (also known as central exchange).

CGM: Computer graphics metafile. A standard file format for electronically stored images.

Character: Letter, numeral, punctuation, control figure or any other symbol contained in a message.

CICS: Customer Information Control System (IBM).

Clock: Shorthand term for the source(s) of timing signals used in synchronous transmission. More generally; the source(s) of timing signals sequencing electronic events.

Cluster: A collection of terminals or other devices in a single location.

CLV: Constant linear velocity. Describes a disk that rotates more slowly when outer radii are being scanned.

COM: Computer output microfilm. A system in which digital data is converted into an image on dry-processed microfilm; see "CD-ROM."

Common carrier: A private data communications utility company that furnishes communications services to the general public.

Communications protocol: The rules governing the exchange of information between devices on a data line.

Composite link: The line or circuit connecting a pair of multiplexors or concentrators; the circuit carrying multiplexed data.

Compression: An encoding technique that save space by eliminating gaps, empty fields, redundancy, or unnecessary data.

Compression algorithms: The formulae according to which digital data sets representing images are compressed.

Concentrator: See "statistical multiplexor."

Conditioning: The addition of equipment to a leased voice-grade channel, enabling the channel to meet specifications for data transmission.

Contention: The facility provided by the dial network or a data PABX which allows multiple terminals to compete on a first-come, first-served basis for a smaller number of computer ports.

CPU: Central processing unit. Portion of a computer that directs the sequence of operations and initiates the proper commands to the computer for execution.

Crosstalk: The unwanted transmission of a signal on a channel that interferes with another adjacent channel.

CSU: Channel service unit.

CY: Calendar year.

D channel: The "data" channel of an ISDN interface, used to carry control signals and customer call data in a packet-switched mode. In the BRI, the D channel operates at 17 kilobits per second; in the PRI, the D channel is used at 64 kilobits per second.

DACS: Directory access and control system.

DAT: Digital audio tape.

Data Integrity: A performance measure based on the rate of undetected errors.

Data rate: The rate at which data moves through, out of or into a device; frequently modified by *peak*, *burst*, *instantaneous*, *sustained*, *average*, or other indicators of the conditions of measurement.

Database: A collection of information; a computer method for organizing and manipulating a database is called a "database management system."

DBMS: Database management system.

DCE: Data circuit terminating equipment. Devices that provide the functions required to establish, maintain and terminate a data transmission connection; for example, a modem.

DDE: Dynamic data exchange.

DDS: (1) Digital Document Storage. A project at the NASA STI Facility, created under the direction of NASA Headquarters Code NTT, to store digitally, transmit electronically, and reproduce optomechanically, the documents kept at the STI Facility to various NASA Centers. (2) Dataphone Digital Service. An AT&T communications service in which data is transmitted in digital rather than analog form, thus eliminating the need for modems.

Decompression: A decoding technique that is a reverses compression to convert what was compressed to the original data.

Defect: An irregularity in a medium that disturbs its ability to store recorded data.

Demodulation: The process of retrieving digital (computer) data from a modulated analog (telephone) signal.

Dial network: A network that is shared among many users, any one of whom can establish communication between desired points, when required, by use of a dial or push-button telephone.

Digital Data: Information transmitted in a coded form (from a computer) represented by discrete signal elements.

Digital image management system: This is a system designed to convert documents into binary (digital) code representing an image of the document and to store that code onto optical media. The digitized image can be reproduced as a paper copy of the original document or displayed as an image of the original document upon request.

Digital Paper: A relatively new optical storage flexible media that has a storage capacity of one gigabyte on a single-sided 5.25-inch optical disk.

Disk: A medium for randomly addressable data storage.

Disk partitioning: The division of one large disk area into smaller user-defined storage blocks.

Document: This is the physical, paper copy, of a NASA Technical Report. Any document referenced in a RECON/STIMS database and retained at the STI Facility is assigned an accession number.

DOR: Digital optical recorder.

DOS: Disk Operating System. The operating system for computers that manages the physical resources of a computer such as disks, memory, displays, etc. UNIX, MS-DOS, OS/2 and VMS are examples.

Downloading: The process of sending configuration parameters, operating software or related data from a central source to remote stations.

dpi: Dots per inch.

DRAW: Direct read after write.

Drive: A machine for reading and, when possible, writing a data storage medium (disk, tape, card, or otherwise); can be optical, magnetic, etc.

DSU: Digital service unit.

DTE: Data terminal equipment.

DTMF: Dual-tone multiple frequency. The frequency of the tones generated by a touch-tone telephone.

DTR: Data-transfer rate.

Dumb terminal: Both hard-copy and VDT-type ASCII asynchronous terminals that do not use a data transmission protocol and usually send data one character at a time.

Duplex transmission: See "FDX."

E-DRAW: Erasable DRAW (see "DRAW").

Emulation: The imitation of a computer system, performed by a combination of hardware and software, that allows programs to run between incompatible systems.

Erasable: Rewritable. See also "M-O."

ESA: European Space Agency.

fax: (noun) Facsimile machine; the electronic transmission of a document page image by a facsimile machine; or the hard-copy output produced by a facsimile machine. (verb) To send document page images via a facsimile machine.

fax board: An add-in board that enables a PC workstation to send or receive a facsimile (fax) transmission. A received fax can be output on a printer connected to the PC.

FCC: Federal Communications Commission.

FDDI: Fiber distributed data interface. An ANSI standard for dual counter-rotating token rings with a bandwidth of 100 Mbps.

FDM: Frequency-division multiplexor. A device that divides the available transmission frequency range into narrower banks, each of which is used for a separate channel.

FDX: Full duplex. Simultaneous, two-way, independent transmission in both directions (4-wire).

FEP: front-end processor

FIFO: First-in, first-out. A queue for storage of commands or data.

File server: A special PC where shared software resources are stored, including the network software that monitors network operation. The file server software manages access to a shared disk and the data on it. File server software is designed specifically for networking and is built to handle the sharing of files in a multiuser environment.

FIPS: Federal Information Processing Standard.

Firmware: Software stored in read-only memory (ROM). See "software."

Flow control: The procedure for regulating the flow of data between two devices; prevent the loss of data once a device's buffer has reached its capacity.

Formatting: The physical format of an optical disk. The preparation of a storage medium with guidance information and a structure for keeping or collecting information for a directory. This collection of material placed on the disk before user data is written is called a "format."

Frequency: The number of cycles per second of a periodic phenomenon; unit is hertz (Hz); see "wave."

FTE: Full-time equivalent.

G: Giga. One billion.

Gb: Gigabit; one billion (2^{30}) bites.

GB: Gigabyte; one billion (2^{30}) bytes.

GEM: Graphics Environment Manager. A DOS-based PC environment from Digital Research Inc.

GPO: U.S. Government Printing Office.

Handling zone: The part of a disk that can be touched by a handling mechanism (for example, in a jukebox).

Header: The control information added to the beginning of a message either a transmission block or a packet.

Hierarchy: An arrangement of memory device types connected to form a series with increasing values of one parameter (such as accessibility) and decreasing values of another parameter (such as cost per bit).

HDL: High-level data link control. The communications protocol defined by the International Standard Organization (ISO).

HDX: Half duplex. Transmission in either direction, but not simultaneous (2-wire).

H-PAD: A mainframe host-based packet assembler/disassembler (see "PAD").

Huffman code: A code used for one-dimensional data compression in the CCITT Group III digital facsimile standard.

Hz: Hertz. A unit of frequency equal to one cycle per second.

i486: Intel's 80486 CPU is fully compatible with the 386 microprocessor, but incorporates the 386 architecture with a 4KB memory cache controller and a floating-point processor all on one chip.

IBM: International Business Machines Inc.

IEEE: Institute of Electrical and Electronics Engineers.

IMG: An image file format created by Digital Research Inc. for GEM. This format is used by Xerox's Ventura Publisher.

Import/export slot: The slot used to add disks to or remove disks from an optical disk jukebox; also referred to as an exchange slot or mailbox.

Interleave: To send blocks of data alternatively to two or more stations on a multipoint system, or to put bits or characters alternately into the time slots in a time-division multiplexor (TDM).

IPL: Intelligent Peripheral Interface.

IPS: Input Processing System.

ISDN: Integrated Services Digital Network. As officially defined by CCITT, ISDN is "a limited set of standard interfaces to a digital communications network." The result is a network that offers end users with voice, data, and certain image services on end-to-end digital circuits.

ISO: International Standards Organization.

Jukebox: An automatic media handler for optical disks and drives; also called a library.

k: Kilo. One thousand.

Kb: Kilobits; 1,024 (2^{10}) bits.

KB: Kilobytes; 1,024 (2^{10}) bytes.

Kbps: Kilobits per second.

KIPP: Kofax Image Processing Platform.

LAN: Local area network.

Leased line: A telephone line reserved for the exclusive use of leasing customers, without interexchange switching arrangements. Also called a private line.

Library: See "jukebox."

Line driver: A signal converter the conditions a digital signal to ensure reliable transmission over an extended distance.

Line turnaround: The reversing of transmission direction from sender to receiver or vice versa when using a half-duplex circuit.

LMS: Lasor Magnetic Storage International Company.

Loaded line: A telephone line equipped with loading coils to add inductance in order to minimize amplitude distortion.

Local line, local loop: A channel connecting the subscriber's equipment to the line terminating equipment in the central office. Usually a numeric circuit (either 2-wire or 4-wire).

lpi: Lines per inch.

LSTAR (1X series): Limited distribution STAR documents. See "STAR."

LU: logical unit.

M-O: Magneto-optic. Information stored by local magnetization of a magnetic medium. Reading is performed optically, through rotation of the plane of polarization of probing light via the Faraday effect or Kerr effect.

M: Mega. One million.

m: Milli. One thousandth (10^{-3}).

Mainframe: A large, expensive, powerful computer intended for centralized application.

Mapping: In a jukebox environment, the process of translating a volume name to a disk's slot number.

MB: megabyte, or one million (2^{20}) bytes.

Mbps: Megabits per second.

MCAV: Modified constant angular velocity. A media format with greater data density than CAV, but without the performance compromise of CLV. See "CAV."

MCLV: Modified constant linear velocity. See "CLV."

Media: Properly, plural of "medium," but widely used as both singular and plural.

Medium: A substance or object on which information is stored; usually refers either to the sensitive coating on a writable device or to the device itself (for example, disk, tape, card, etc.).

Menu: The list of available software functions for selection by the operator, displayed on the computer screen once a software program has been entered.

- Migration:** The movement of data up and down within a hierarchy of storage devices.
- MIL:** Military.
- MIL-Spec:** Military specification.
- MIPS:** Million instructions per second; a measure of the speed of a computer.
- Mnemonic code:** Instructions for the computer written in a form that is easy for the programmer to remember. A program written in mnemonics must be converted to machine code prior to execution.
- Modem:** Modulator-demodulator. A device used to convert serial digital data from a transmitting terminal to a signal suitable for transmission over a telephone channel, or to reconvert the transmitted signal to serial digital data for acceptance by a receiving terminal.
- Modulation:** Modifying some characteristics of a wave form.
- Mount:** (1) An operation that makes the contents of a volume available to a file system; (2) The act of determining the location of a volume in a jukebox and insuring it is spun up in a drive.
- MS-DOS:** Microsoft Disk Operating System.
- ms:** millisecond. One thousandth of a second (2^{-3} seconds).
- MSP:** An image file format for Microsoft Windows Paint program.
- MSS:** Mass storage system.
- MTBF:** Mean time between failure. The average length of time that a system or component works without failure.
- Multidrop line:** A single communications circuit that interconnects many stations, each of which contains terminal devices.
- Multiplex:** The simultaneous transmission of many signals on one channel. These signals can be separated in frequency, time, phase, or any other dependable means.
- Multiplexor:** A device used for division of a transmission facility into two or more subchannels, either by splitting the frequency band into narrower bands (frequency division or by allotting a common channel to several different transmitting devices one at a time (time division).
- Multipoint line:** A single communications line or circuit interconnecting several stations; usually requires some kind of polling mechanism to address each connected terminal with a unique address code.

- N/A:** Not available.
- n:** Nano. One billionth.
- NASA:** National Aeronautics and Space Administration.
- NCP:** Network control program.
- NMA:** National Micrographics Association.
- Node:** A point of interconnection to a network. Normally, a point at which a number of terminals or tail circuits attach to the network.
- Noise:** Unwanted signals present on a medium, either before or after recording.
- NPSS:** NASA Packet-switching Network.
- NPV:** Net present value.
- ns:** Nanosecond. One billionth of a second (2^{-9} seconds). Also abbreviated as nsec.
- NSN:** NASA Science Network.
- OA:** Office automation. The use of electronic and computer devices in office applications.
- OCR:** Optical character recognition. A process of recognizing characters or numbers in printed or bit-mapped form through the use of optical scanning technology.
- ODD:** Optical data disk.
- OEM:** Original equipment manufacturer.
- OLTP:** Online transaction processing.
- OMDR:** Optical memory disk recorder. A DRAW device used to write analog or digital information to an optical disk.
- OD:** Optical disk. A disk that is read from and/or written to by light, generally laser light; such a disk can store video, audio, or digital data.
- Optical file server:** A PC with a high-capacity optical disk acting as a file server. See "file server."
- OROM:** Optical read-only memory.
- OS:** Operating system. A specialized program that provides a computer with its basic personality, including its interfaces displays, and memories (see "access method"). Two such microcomputer operation systems are CP/M and MS-DOS. One for larger microcomputers and minicomputers is UNIX. Two mainframe operating systems are VM and MVS.

OSI: Open Systems Interconnect. A mass-storage interface standard promulgated, in a striking case of acronymic symmetry, by the ISO.

Overhead: In computer jargon, the amount of storage or other resources used to accomplish some task. For example, error correction code added to data might increase total storage requirements by 20 percent, which would be referred to as the overhead of that error correction code.

PABX: Private automatic branch exchange. A user-owned, automatic telephone exchange that accommodates the transmission of calls to and from the public telephone network.

Packet: A group of bits (including data and call control signals) transmitted as a whole on packet-switched network. Usually smaller than a transmission block.

Packet-switching: A technique of data multiplexing in which individual data streams are divided into "packets" (which are identified by the sending and receiving address) and sent out into the common channel; basic to the Ethernet LAN.

PAD: Packet assembler/disassembler. An interface between a terminal or computer and a packet-switched network.

Parity bits: Extra bits added to blocks of data to provide a very simple form of error detection and, sometimes, correction. See "framing."

Parity check: The addition of noninformation bits that comprise a transmission block to ensure that the total number of 1's is always either even (even parity) or odd (odd parity); used to detect transmission errors.

PC: Personal Computer.

PC DOS: Personal Computer Disk Operating System. IBM's version of MS-DOS modified for use on its PCs.

PCX: An image file format created by ZSoft Inc. for its PC Paintbrush program.

PDN: Public Data Network.

Peripheral: A device that attaches to a computer (such as a disk drive, printer, or monitor).

Phase modulation: One of three ways of modifying a sine wave signal to make it carry information. The sine wave, or carrier, has its phase changed in accordance with the information to be transmitted.

Pixel: Picture element. The smallest resolvable dot in an image display. Also abbreviated as "pel."

Point-to-point: A connection link between two, and only two, pieces of equipment.

Polling: A means of controlling devices on a multipoint line.

Port: A computer interface capable of attaching to a modem for communicating with a remote terminal.

ppm: Pages per minute.

PRI: Primary Rate Interface. The ISDN specification for the interface at each end of high-volume trunks linking PBX and central office facilities or connecting network switches to each other. The primary rate consists of 23 B or bearer channels operated at 64 Kbps and a single D or data channel also functioning at 64 Kbps. The combined signal-carrying capacity is 1.544 Mbps—equivalent to a digital signal hierarchy level of DS-1.

Private line: See “leased line.”

Processed requests: This phrase indicates those requests for reproduced NASA Technical Reports that are accepted and processed by reproducing a paper copy from microfiche or from the original stock copy.

Protocol: A formal set of conventions governing the formatting and relative timing of message exchange between two communicating systems.

PSCN: Program Support Communications Network.

PSN: Packet-switching network.

QLV: Quantized linear velocity. See “MCAV.”

Queue: A waiting line or area.

R-COM: Raster format computer output microfilm. Device to transfer data from optical digital storage to microfilm; see “COM.”

RAM: Random access memory.

Raster: The scanning lines that form the image or graphic output on a computer display (see “vector”).

Read-time: In reference to the recording of an event means recording the event at the same time as it occurs; an example of non-real-time recording would be making a replica from a master recording.

RES: An image file format developed by Xerox Systems Inc.

Response time: The elapsed time between the generation of the last character of a message at a terminal and the receipt of the first character of the reply. It includes terminal delay and network delay.

RF: Radio frequency.

RFP: Request for proposal.

RFQ: Request for quotation.

RPCS: Registration and product control system.

ROM: Read-only memory.

Run length encoding: The basis for most of the data compression methods used in digital representation of images; based on transmitting numbers describing the lengths of white and black regions of an image rather than sending separately each black or white pixel.

Scanner: A device that resolves a two-dimensional object, such as a business document, into a stream of bits by raster scanning and quantization.

SCSI: Small computer systems interface. An intelligent device interface allowing devices to be connected serially; commonly pronounced "scuzzy."

SDLC: Synchronous data link control. IBM standard protocol superseding BSC.

Sector: A triangular section of a disk surface within a track. A block of data is addressed by its track and sector numbers.

Seek time: The time required to make a storage unit ready to access a specific location by selection or physical positioning.

Serial transmission: The most common transmission mode; in serial, information bits are sent sequentially on a single data channel.

SGML: Standard Generalized Markup Language. A standard method of tagging an electronic document file for indicating typesetting and layout formats.

Simplex transmission: Data transmission in only one direction.

Slot number: Numeric indicator of a location within a jukebox; could be a storage slot, optical drive or the mailbox (import/export slot).

SNA: System Network Architecture. The unified software architecture across computing platforms promoted by IBM.

Software: A computer program or set of programs held in some kind of storage medium and loaded into RAM for execution (see "firmware").

SPAN: Space Physics Analysis Network.

STAR: Scientific and Technical Aerospace Reports. STAR is a major component of a comprehensive NASA information system covering aeronautics, space, and supporting disciplines.

Statistical multiplexor: A device used to divide a data channel into two or more channels of lower average speed, dynamically allocating channel space according to demand in order to maximize throughput.

STI Facility: The NASA Scientific and Technical Information Facility.

STIMS: Scientific and Technical Information Modular System.

Storage: The capability of a computer or related device to hold data and return it on demand.

Switched line: A communications link for which the physical path can vary with each usage, such as the public telephone network.

Synchronous modem: Modem that carries timing information with data.

Synchronous transmission: Transmission in which data bits are sent at a fixed rate, with the transmitter and receiver synchronized. Synchronized transmission eliminates the need for start and stop bits.

System: Any combination of things coordinated to accomplish some function.

T: Tera. One trillion (10^{12}). For example, 2TB is 2,000,000,000 bytes.

T1: The most popular digital copper-wire transmission system and the rate at which it operates (about 1.5 Mbps). This operating rate is equal to the DS-1 rate of the digital transmission hierarchy.

Tail circuit: A feeder circuit or an access line to network node.

TDM: Time-division multiplexor. A device that accepts multiple channels on a single transmission line by connecting terminals, one at a time, at regular intervals interleaving bits (bit TDM) or characters (character TDM) from each terminal.

Throughput: The volume of work or information flowing through a system. Particularly meaningful in information storage and retrieval systems, in which throughput is measured in units such as accesses per hour.

TIFF: Tagged Image File Format. Developed by Aldus Corporation, TIFF is the de facto standard method for storing images captured by a scanner.

Timesharing: A method of computer operation that allows several interactive terminals to use one computer. Although the terminals are actually served in sequence, the high speed of the computer makes it appear as if all terminals were being served simultaneously.

T-PAD: A terminal-based packet assembler/disassembler (see "PAD").

Track: A circular path on which information can be stored on a disk surface. A track encompasses one rotation of the disk, and is divided into sectors.

Transfer rate: The rate at which data is transferred to or from a device; especially the reading or writing rate of a storage peripheral. Usually expressed in kilobits or megabits per second (Kbps or Mbps).

Trunk: A single circuit between two points, both of which are switching centers or individual distribution points. A trunk usually handles many channels simultaneously.

TSO: Time share option.

Turnaround time: The actual time required to reverse the direction of transmission from sender to receiver or vice versa when using a half-duplex circuit. Time is required for line propagation effects, modem timing and computer reaction.

Two-wire: Circuit that indicates information signals in both directions for data carried by the same path.

Unmount: (1) An operation that makes the contents of a volume unavailable to a file system; (2) The act of spinning down a drive, removing its disk, and placing it in a storage slot within a jukebox.

Vector: A representation of a line drawing by listing the beginning and end points of all the lines; see "raster."

Voice-frequency: Frequency in part of the audio frequency range essential for the transmission of commercial-quality speech.

Voice-grade line: A channel that is capable of carrying voice frequency signals.

Volume: (1) One unit of removable storage; the contents of one optical disk surface; (2) A "named" optical disk surface in a jukebox; its name (label) is usually stored in a prescribed location on its surface.

VTAM: Virtual telecommunication access method.

WAN: Wide area network.

Wave: One complete cycle of a change in electromagnetic intensity or potential.

Wideband: See "broadband."

WMRA: Write many, read always.

WORM: Write once, read many times.

Write-once: Can be written to but not erased.

X.25: CCITT standard governing interface between data terminal equipment (DTE) and data circuit terminating equipment (DCE) for terminals operating in the packet-switched mode on public data networks.

X.25-PAD: A packet assembler/disassembler that permits communication between non-X.25 devices and the devices in an X.25 network (see "PAD").

ZCAV: Zoned constant angular velocity. See "MCAV."

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